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JOURNAL OF ANATOMY

THE PRIMORDIAL CRANIUM OF MICROTUS AMPHIBIUS (WATER-RAT), AS DETERMINED BY SECTIONS AND A MODEL OF THE 25-MM. STAGE. WITH COMPARATIVE REMARKS.

By EDWARD FAWCETT, M.D., *Professor of Anatomy, University of Bristol.*

THE specimen about to be described was kindly afforded me by Prof. J. P. Hill, of University College, London; it was cut by me into serial sections of 20 μ thick and stained with Mallory's triple connective-tissue stain, a stain which stains cartilage very well and (if properly manipulated) bone magnificently even in its very earliest condition. As a corrective another specimen was sectioned of 17·5 mm. total length, for which I am indebted to my colleague Dr W. D. Henderson; but of this specimen no model was made, nor was it necessary, for the conditions in the two were practically identical, the latter no doubt having shrunk somewhat in the various processes of hardening. In both ossification had proceeded to a degree which I had not anticipated, but the outlines of the ossifying cartilage were sufficiently clear to easily determine.

A model of the 25-mm. specimen was made at a magnification of fifty diameters by the wax-plate method. Both neural and visceral skeleton were modelled, and, as far as possible, the various bones were modelled too. Where accessory cartilages appear in connection with the covering bones, these are represented. Nerves and blood-vessels were, in cases of interest, modelled *in situ*, but for the most part were removed later. A separate model of the auditory capsule with membranous labyrinth was made.

GENERAL DESCRIPTION OF THE COMPLETE MODEL.

In this description I have to a certain extent been guided by the very exhaustive description of the primordial cranium as given by Voit in the *Anatomische Hefte*, which will stand as a model of what a description ought to be; but, in the light of what seems to me to result from a prolonged

series of researches into the primordial cranium of various mammals, some modifications seem desirable.

I have therefore determined on the following mode of description, viz.: firstly, to describe that part more especially connected with the central nervous system; secondly, to give an account of that part derived more particularly from the visceral appendages; thirdly, to describe the bones.

The Primordial Neural Cranium.

In describing this part in the light of what seems to result from my general researches I have adopted a different plan from that usually done, and therefore will consider the primordial neural cranium as consisting of the following parts:—

1. A central stem, to which are appended, at more or less constant positions,
2. Appendages to the central stem;
3. Lateral structures;
4. Commissures binding these lateral structures together;
5. Dorsal structures, viz. those which lie dorsal to the encephalon and form a cartilaginous roof to the cavum cranii.

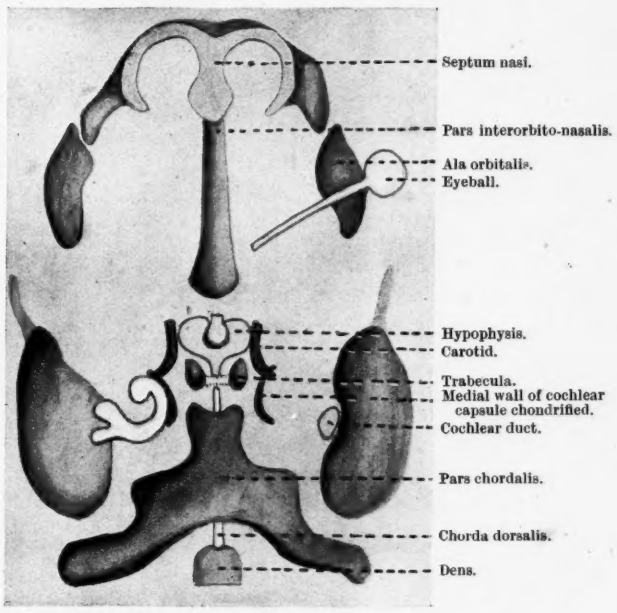
1. The Central Stem.

The central stem (Pls. 1, 2) stretches from the anterior margin of the foramen magnum to the tip of the nose, and as far forwards as the back of the nasal capsule consists of a long flattened plate, wide behind but narrowing as it is traced forwards to the hinder part of the nasal capsule. As far forwards as the region just named the central stem is wider than deep; but once it has been included in the nasal capsule (of which it forms the septum) it suddenly increases in depth (Pl. 9), so that its vertical height is very much greater than its transverse width.

Constituent Parts of the Central Stem.—So far as my experience goes, the central stem appears to be made up, in the various mammals examined, of the following parts, ontogenetically: (1) a hinder broad part closely associated with the chorda-dorsalis, differing in various genera in its relation to that structure. This part may be termed the *chordal part* (pars chordalis) (Pls. 1, 2). Anterior to the chordal part comes (2), a part of variable breadth, but still of considerable breadth, which is formed from trabeculæ, and may be therefore designated the *trabecular part* (pars trabecularis) (Pls. 1, 2). This is followed anteriorly by a part which posteriorly lies between the optic foramina, more anteriorly between the orbital cavities, and more anteriorly as the septum nasi. All these parts

taken together form (3) the *interorbito-nasal septum* (Pls. 1, 2, 9). Ontogenetically these parts all chondrify independently of one another in Talpa, Cavia, Tatusia novemcincta, and ? Homo. In the latter the trabeculæ are formed quite independently of the pars chordalis and of one another, but I do not know if they arise independently of the interorbito-nasal septum.

Although I have no specimen of Microtus young enough to state definitely that this is the mode of development in Microtus, yet it seems



TEXT-FIG. 1.—Talpa. Chondrocranium of 11-mm. embryo, viewed from below.

justifiable to describe the central stem at the stage modelled on the same lines; and although no distinct traces of such subdivision are evident at this stage, all being now fused, it is not difficult to indicate with some precision their limits.

Detailed Description of the Central Stem.—The chordal part of the central stem is roughly triangular in form as seen either from above or below (Pls. 1, 2). The basal region of this triangular plate forms the anterior concave margin of the foramen magnum. The apical region is marked by a small median foramen (Pl. 1), the remains of the basi-cranial fenestra

through which the chorda-dorsalis dips down from the dorsal aspect of the chordal plate towards the pharyngeal root. The sides of the triangular plate are in relation with the auditory capsules (Pls. 1, 2) antero-laterally, whilst postero-laterally they are directly continuous with those outrunners of this region which I shall allude to as the exoccipital cartilages (pila occipitalia) (Pls. 1, 2), an imaginary antero-posterior line drawn through the hypoglossal canals only separating this part of the central stem from the exoccipitals which lie lateral to its basal angles. The pars chordalis is only directly connected with the auditory capsule through a cartilaginous commissure which, starting about the middle of the lateral border, fuses with the intero-medial aspect of the "vestibular" segment of the pars cochlearis, thus breaking up into two parts an otherwise large fissure between the pars chordalis and the auditory capsule. That part of the fissure which lies in front of this cartilaginous commissure—and which from its mode of development may perhaps be termed the *chordo-cochlear commissure* (Pls. 1, 2)—is the basi-cochlear fissure, whilst that part of the common fissure which lies behind the commissure in question is the foramen jugulare (Pls. 1, 2). To the under aspect of this chordal segment of the central stem are attached the prevertebral muscles which reach the head, and on the under aspect of the basal border at its most lateral part on each side is that part of the condyle which belongs to the pars chordalis.

Ossification has commenced in the pars chordalis, both of the ento-chondral and perichondrial type, and the chorda dorsalis can be traced along the whole length of the dorsal aspect of the ossifying cartilage, but deep to the perichondrial bone. This pars chordalis is therefore hypochordal in position. The chorda-dorsalis (Pl. 1) dips down through a small foramen at the anterior limit of the pars chordalis to reach the dorsal aspect of the pharyngeal mucous membrane, but it cannot be traced further onward at this stage. The foramen through which the chorda-dorsalis passes is the remnant of a much larger one in the younger stages, and represents the gap between the pars chordalis and the pars trabecularis—in other words, the basi-cranial fenestra of reptilia. In the stage modelled it lies opposite the anterior limit of the basi-cochlear fissure (Pl. 1), and exactly in the mid-line. In front of a line drawn transversely through this foramen we reach the pars trabecularis.

The Pars trabecularis (Pls. 1, 2).—That part formed by the fused trabeculæ, and in intimate relation with the hypophysis, is of about the same width as the anterior part of the pars chordalis. From behind forwards, as seen from above, it shows first a slight transverse ridge, the crista sellaris (Pl. 1); in front of this is a shallow hollow, the fossa hypophyseos

(Pl. 1), in which rests the hypophysis, and whose floor was no doubt at an earlier state perforated by its stomodœal duct. In front of the hypophyseal fossa the pars trabecularis narrows somewhat, and passes without line of demarcation histologically into the interorbito-nasal septum; but from this septum at its hindmost part laterally two triangular processes are given off, one on each side—alæ hypochiasmatæ (Pls. 1, 2); a line drawn transversely through their hinder edges will separate the pars trabecularis from the septum interorbito-nasalis. The prehypophyseal segment of the pars trabecularis is unusually long in Microtus.

From each side of the pars trabecularis two processes or commissures project, viz.: one, a more posterior, connecting the pars trabecularis with the cochlea behind the carotid artery; the other running also laterally and then posteriorly from the side of the pars trabecularis and in front of the carotid artery to the upper aspect of the apex cochleæ. These commissures may be termed respectively the *posterior* and *anterior trabeculo-cochlear commissures* (Pls. 1, 2, 5). Between the two lies the *foramen caroticum* (Pls. 1, 2, 5). From the front of the middle of the anterior trabeculo-cochlear commissure the *ala temporalis* projects in a general outward direction, and for this reason, perhaps, the term alicochlear commissure is the one usually given to what I have termed the anterior trabeculo-cochlear commissure. The posterior trabeculo-cochlear commissure seems to have escaped attention, save in the mole, in which it persists as a narrow bar, and as such is figured by Fischer, but not described. This commissure is narrow in the mole, but tends in many other animals to so increase in antero-posterior width as to ultimately fuse with the chordo-cochlear commissure and so obliterate the basi-cochlear fissure, of which it forms the anterior limit normally. This is evidently the case in the calf, ferret, hedgehog, and man. In the cat the basi-cochlear fenestra is persistent, and so it is in the rabbit (Voit) and in Tatusia. Only a few emissary veins pass through it when persistent.

The pars trabecularis in the mole arises as two cylindrical cartilaginous rods placed on each side of the hypophyseal duct at the 10–12-mm. stage; in Tatusia novemcincta as a perforated isolated plate interposed between, but independent of, both interorbito-nasal septum and pars chordalis of the central stem, at 12 mm.; in man as two precartilaginous rods on each side of the hypophyseal duct, independent of one another and of the pars chordalis, but as the interorbital septum is not chondrified at the stage in question, viz. 13·5 mm., it could not be determined whether it was independent of this.

The Pars interorbito-nasalis (Pls. 1, 2, 9).—This, to be alluded to subsequently as the interorbito-nasal septum, is recognised at its hindmost

part by its giving off two triangular processes—the alæ hypochiasmatæ. These processes, triangular in form—since they always serve at some time or other for the attachment of one or other of the rectus system of muscles of the eyeball, they might as well be termed *processus musculosi*,—may be taken as indicating at their hindmost points the posterior limit of the interorbito-nasal septum. Laterally, in front of the alæ hypochiasmatæ, the inter-orbital part of the interorbito-nasal septum is bounded by the two optic foramina (Pls. 1, 2), which in Microtus are incomplete behind, recalling the condition observed in Metatheria. Anterior to these foramina the inter-orbito-nasal septum is fused with the anterior narrow limb or root of the ala orbitalis of each side, in front of which the septum is now narrowed and forms the median or septal boundary of the two orbito-nasal fissures and the two orbital cavities. It is customary to limit the term inter-orbital septum to that part which lies septal to the two orbital cavities, but from its mode of development I have here preferred to carry the septum further back, *i.e.* to the level of the hindmost part of the alæ hypochiasmatæ.

Beyond the orbito-nasal fissures the interorbito-nasal septum enters on its intra-narial stage, and may now be called the *septum nasi* (Pls. 1, 2, 9). As such its height greatly exceeds its width, and this more especially as it is traced forwards. The upper edge is partly subcerebral, say for one-third of its extent; the remainder is præcerebral.

The subcerebral part of the upper border of the septum nasi rises rapidly as it is traced forwards, until at its anterior end it culminates in a small backwardly curved *crista galli* (Pls. 1, 9).

From the hindmost part of each lateral border of this part of the septum the posterior wall of the lateral nasal capsule projects as the *planum antorbitale* (Pls. 1, 9, 10), and from the remainder of the lateral margin the *lamina cribrosa* (Pls 1, 9,) runs outwards. From the crista galli forwards the upper border of the septum nasi is præcerebral; and, at first flush with the rest of the tectum nasi, of which it forms the median part, it gradually sinks to a lower level so as to lie at the bottom of a median shallow longitudinal furrow, the *sulcus dorsalis nasi* (Pls. 1, 9). The subcerebral and præcerebral parts of the septum nasi are inclined to one another at an angle convex upwards.

The inferior border of the septum nasi (Pls. 2, 3, 9) lies almost horizontally and forms only a very obtuse angle with that part of the central stem behind it; in fact, so obtuse is this angle that the two are almost in the same horizontal line—a feature which seems to characterise the chondrocrania of all mammals which I have examined up to Carnivora at some stage or other of their development, *e.g.* Dasyurus

viverrinus, Tatusia, Talpa, Erinaceus, Bos, Ovis, Lepus. In the 12-mm. stage of Tatusia the angle is more acute, and has straightened out at the 17-mm. stage.

The lower border of the septum is thicker than the upper one, and it is convex from side to side; for the most part it is free, but posteriorly it is directly continuous with the hinder wall of the nasal capsule, and anteriorly, shortly behind the tip of the nose, it is directly continuous with the floor of the nose at the *lamina transversalis anterior* (Pl. 2, fig. 1). Between the latter and the hinder end of the nasal capsule, the lower part of the septum nasi is in close relation on each side with the *paraseptal cartilage* and the *lamina transversalis posterior* (Pls. 2, 9, fig. 1), a very narrow septo-paraseptal fissure only intervening. The septum ends anteriorly by bifurcating into two laminæ which, recurving, form on each side the *cupula nasi anterior* (Pls. 1, 2, 9).

A small perforation is met with in the septum some distance above the anterior margin of the lamina transversalis anterior, and is termed the *foramen internasale* (Pl. 9). This foramen in the actual specimen is closed by fibrous tissue covered by the mucous membrane of the two narial passages. A slight swelling is met with not far from the anterior end of the septum, which, when covered by mucous membrane, simulates a septo-turbinal.

The total length of the interorbito-nasal septum amounts to almost the equal of the remainder of the central stem behind it.

2. Structures appended to each Side of the Central Stem.

These structures are from behind forwards.

(*a*) The exoccipital cartilage or pila occipitalis.
(*b*) The auditory capsule.
(*c*) The ala temporalis.
(*d*) The ala orbitalis.
(*e*) The lateral nasal capsule.

The two last may also be regarded as lateral structures, and may perhaps be considered later in that category.

(*a*) *The Exoccipital Cartilage.*

Each exoccipital cartilage (Pls. 1, 2, 3) springs from the corresponding basal angle of the triangular chordal part of the central stem, and it is in direct histological continuity with it. As before said, an imaginary line drawn antero-posteriorly through the hypoglossal canals—of which there are two in Microtus, viz. a smaller anterior and a larger posterior—will indicate

its commencement. The subsequent ossification more precisely distinguishes the exoccipital cartilage from the pars chordalis. The under aspect of this region lateral to the hypoglossal canals forms the greater part of the occipital condyle. The anterior margin of the exoccipital cartilage projects freely under the cochlear part of the auditory capsule, from which it is separated by the foramen jugulare; and more laterally the same anterior margin is prolonged at first forwards under the pars canalicularis of the auditory capsule as a thin horizontal plate, the lamina alaris (Pl. 2), which is overlain by the 9th, 10th, and 11th cranial nerves, as well as by the processus perilymphaticus from the interior of the auditory capsule, and by the lateral sinus. Only a small fissure, itself hidden to a large extent by the terminal part of the lateral sinus, and visible only from the cavum cranii, separates the lamina alaris from the pars canalicularis of the auditory capsule. The fissure is the *recessus jugularis* (Pl. 5). As one follows outwards the anterior margin of the exoccipital cartilage, one finds that it projects laterally underneath the pars canalicularis of the auditory capsule, and here a certain amount of superficial fusion takes place between the two. The lateral projection is quite small in amount, being very different from that figured by Voit as the paracondyloid process of the rabbit; but it may be regarded as equivalent to the root of the *paracondyloid process* (Pl. 3) of the rabbit, and will be named as such here. The lamina alaris in this specimen is in process of ossification, both entochondral and perichondrial, the latter greatly predominating, but there is as yet no sign of ossification in the paracondyloid process. The anterior border of the exoccipital cartilage above the level of the paracondyloid process may be now traced upwards, arching over the hinder margin of the pars canalicularis as far as the cupula of the latter. In this part of its course this border is separated from the auditory capsule by a well-marked fissure, which may be named the *fissura occipito-capsularis inferior* (Pls. 3, 4). On looking through this fissure from the exterior the lateral venous sinus may be seen.

The posterior margin of the exoccipital cartilage, a margin which is also median, forms a great part of the antero-lateral boundary of the foramen magnum. Opposite the cupula posterior of the auditory capsule the exoccipital cartilage may be regarded as ending; for though at this stage in Microtus no histological difference is evident, a distinct fissure exists in the calf at 19 mm., in the hedgehog at 25 mm., and in Tatusia novemcincta at 17 mm. In Microtus, as no histological boundary seems to limit the upward extent of the exoccipital cartilage at this stage, one may say that this cartilage runs directly into the supraoccipital cartilage above it (Pls. 3, 4). The supraoccipital cartilage, however, will be dealt with later.

(*b*) *The Auditory Capsule* (Pls. 1, 2, 3, 4, 5, 6, 7, 8).

This exceedingly complicated structure, which, taken as a whole, may with Voit be described as approximately ovoidal in form, whose long axis lies almost in the horizontal plane, contains the membranous labyrinth, and owes its general form especially to the structure composing this labyrinth. Thus the hinder cupola-like termination is caused by the bifurcation of the hind end of the crus commune into anterior (superior) and posterior semicircular canals, whilst the anterior cupola contains the anterior blind end of the ductus cochlearis. Two main parts are readily distinguished in the auditory capsule, viz.: a posterior—the pars posterior or pars canalicularis, which lies behind the plane of the foramen jugulare, and more particularly over the horizontal part of the exoccipital cartilage, and which forms the lateral wall in great part of the cerebellar segment of the cavum cranii; and an anterior—the pars anterior or pars cochlearis, which converges towards its fellow and the central stem, and so compresses the latter to a much smaller width anteriorly than posteriorly.

The auditory capsule is moored by various commissures to neighbouring parts of the chondro-cranium (Pls. 1, 2, 5). Thus the pars cochlearis by three distinct commissures is attached to other parts, as follow, viz.: an *anterior*, or anterior trabeculo-cochlear (so-called alicochlear), commissure stretches from the upper aspect of the cupula cochlearis forwards on the outer side of the carotid foramen to the so-called processus alaris of the corresponding trabecula; another, the posterior trabeculo-cochlear commissure, passes from the medial upper aspect of the cupula cochlearis medial to the foramen caroticum to the corresponding trabecula opposite the crista transversa, such as that is in Microtus; a third, which connects the hinder medial part of the pars cochlearis with the chordal segment of the central stem, may be called the chordo-cochlear commissure. This commissure separates the basi-cochlear fissure or fenestra in front from the foramen jugulare behind.

The pars canalicularis is very slightly and only superficially connected directly with the paracondyloid process of the exoccipital. At its hinder pole it is fused with the commencement of the supraoccipital cartilage (Pls. 3, 4), or perhaps in some cases, too, at this region with the upper end of the exoccipital where that is confluent with the supraoccipital cartilage. Between this commissure and the one between the pars canalicularis and the paracondyloid process of the exoccipital a narrow fissure—the *inferior (posterior) occipito-capsular fissure*—is found (Pls. 3, 4). Next, the anterior half of the upper margin of the pars canalicularis is connected with the orbito-parietal commissure and the anterior process of the supraoccipital

cartilage by the *parietal plate* (Pls. 3, 5). Between the parietal plate and the posterior commissure of the pars canalicularis is a fissure, the *superior occipito-capsular fissure* (*v.* fissura parieto-capsularis). The anterior part of this fissure transmits the lateral jugular vein from the interior of the skull, and is sometimes called the *foramen jugulare spurium*. In front of the parietal plate the auditory capsule is separated from the orbito-parietal commissure by the large *fenestra spheno-parietalis*. As Voit says for the rabbit, "Die Form der ganzen Labyrinthkupsel wird so sehr von ihrem Inhälte, dem häutigen Labyrinth bestimmt, dass ich es für zweckmässig halte, hier die Abbildung eines Modelles eingefügen . . . von dem häutigen labyrinth. . . ." So in the description, which follows here very closely that given by Voit for the rabbit, it will be seen that the external form of the capsule is intimately dependent on that of its contents.

The Pars canalicularis (Pls. 1, 2, 3, 4, 5, 6, 7, 8) contains especially the utricle and the semicircular canals, and is influenced in its entire form chiefly by the course of the latter. It is pyramidal in form, *i.e.* a three-sided pyramid whose borders are clearly formed by the projections caused by the semicircular canals which run in the interior. These borders, which from their position may be named superior, infero-lateral, and infero-medial, all converge posteriorly on the posterior pole of the pars canalicularis. Three surfaces are to be distinguished, viz. a supero-medial, a lateral, and an infero-medial.

The Borders (Pls. 5, 6, 7).—The upper border or *prominentia semicircularis anterior* commences at the posterior pole, ascends in an arched fashion in a forward direction to end anteriorly in an ill-marked prominence, the *prominentia utriculo-ampullaris superior*. This prominence is rendered indistinct by the *parietal plate* springing from the region where it is found, and the upper border itself is only visible from within, since it is overlapped by the *opercular process* of the anterior prolongation of the supraoccipital cartilage (tectum synoticum). Along this upper border runs the *sinus sigmoideus*, from the region of the foramen jugulare spurium to the posterior pole of the pars canalicularis.

The Infero-lateral Border (Pls. 3, 4, 6)—*prominentia semicircularis posterior*—commences at the pole of the pars canalicularis and runs forwards, outwards, and downwards at an angle of about 70° with the upper border to end near the inferior basal angle of the lateral surface. Not far from the anterior end of the prominentia semicircularis posterior commences the prominentia semicircularis lateralis, but this will be described along with the lateral surface of the pars canalicularis.

The Infero-medial Border of the pars canalicularis (Pls. 5, 7) commences behind at the posterior pole, forms the upper boundary of the

sulcus sigmoideus, in which the sinus sigmoideus lies, and is caused by the *prominentia cruris communis* in its hinder part and more anteriorly by the arch of the posterior semicircular canal; anteriorly it ends in a rounded swelling, the prominentia utriculo-ampullaris posterior, just below and behind the meatus auditorius internus. The prominentia cruris communis is perforated by a small canal for the ductus endolymphaticus (Pls. 5, 7); behind this canal is a groove which later sinks into a large foramen leading into the site of bifurcation of the crus commune into anterior and posterior semicircular canals. The groove is caused by the pressure of the saccus endolymphaticus.

The Surfaces (Pls. 1, 2, 3, 4, 5, 6, 7, 8).—The lateral surface of the pars canalicularis is triangular in form, with apex of triangle backwards at the cupula posterior. The upper and lower sides of the triangle are, as we have seen, formed respectively by the prominentia semicircularis superior and prominentia utriculo-ampullaris superior and the prominentia semicircularis posterior, and the upper side has projected upwards from about its anterior third the parietal plate (Pl. 5).

The base of the triangular lateral surface is of interest in that it gives forwards at its upper angle the tegmen tympani (Pls. 3, 6), which is a curved shell-like cartilage projected forwards over the incus and malleus cartilages, and medially it is fused with the lower part of the parietal plate and with the lower edge of the orbito-parietal commissure; below the tegmen tympani, the base projects as the crista parotica (Pls. 3, 6), which is separated from the tegmen tympani above by a notch, the incisura incudis. The crista parotica, itself somewhat pyramidal in form, by its apex gives attachment to and is fused with the styloid process, between which and the lower side of the crista parotica the facial nerve emerges, the site of emergence being the *primary stylomastoid foramen*. Below this a small notch interrupts the base, the *incisura stapedii* (Pl. 6), which lodges the hindmost end of the stapedius muscle. Below this again is a slight elevation which may from its position be termed *mastoid process*, but it does not give origin to any muscles, nor does it project in any way like that of the rabbit as figured by Voit.

The surface enclosed by these three sides, viz. the *lateral surface*, is directed somewhat backwards as well as outwards. This surface is marked near its middle by a curved almost horizontal ridge, a ridge which, slightly concave upwards, is caused by the out-bulging of the fossa subarcuata superior, and may be therefore termed the *prominentia subarcuata superior* (Pl. 6). From the base of the crista parotica another semicylindrical ridge runs downwards and backwards towards the anterior end of the prominentia semicircularis posterior. This ridge is the *prominentia*

semicircularis lateralis. A triangular hollow is now mapped out between the three just-named prominences, bounded above by the prominentia subarcuata superior, below and behind by the prominentia semicircularis posterior, below and in front by the prominentia semicircularis lateralis. This area corresponds with the solid mass of cartilage intervening between the fossa subarcuata superior and the cavities of the lateral and posterior semicircular canals, and which is termed the *massa angularis.*

The lateral surface of the pars canalicularis is overlapped from above as far as the most prominent part of the prominentia subarcuata superior by the *opercular process* of the anterior prolongation of the supraoccipital cartilage.

The Medial or Supero-medial Surface (Pls. 5, 7, 8), like the lateral, is triangular in form, the upper side of the triangle being formed by the prominentia semicircularis anterior, which is better marked from this aspect than the lateral. The lower side of the triangle is formed to a large extent by the *prominentia cruris communis,* but more anteriorly by the *prominentia utriculo-ampullaris inferior.* The base of the triangular surface, which is anterior, is an imaginary line drawn vertically through the hinder part of the meatus auditorius internus, commencing above at the prominentia utriculo-ampullaris superior and ending below at the prominentia utriculo-ampullaris inferior. A large part of this surface is sunk beneath the prominentia semicircularis anterior to form the *fossa subarcuata anterior* (Pls. 5, 7), a fossa which, ovoidal in form, is very deep everywhere, but below and in front is directly continued by a foramen of considerable size into the vestibular cavity, and on one side the middle of the floor of this fossa subarcuata anterior was perforated to allow of blood-vessels passing through to the exterior. This fossa seems to vary in depth at different ages, for in the cellular and precartilaginous condition it is scarcely present, but later it gradually deepens until it is only separated from the exterior by a thin wall of cartilage, which is the upper part of the massa angularis. This fossa frequently goes by the name of floccular fossa; perhaps the term paraflocçular would better meet the case. It must, however, be at a comparatively late period of fœtal life that this body occupies this fossa, for I have only once seen it so doing, and that in Miniopterus Schreibersi, at the 17-mm. stage.

The Infero-medial Surface (Pls. 5, 7) is only to a slight extent visible from within the cavum cranii. It is for the most part directed towards the exoccipital and particularly to the lamina alaris thereof, between which and the inferior medial surface in question is a narrow fissure, *the recessus supra-alaris* (Pl. 5), visible from the interior of the cavum cranii, and which in the region of the posterior (inferior) occipito-capsular fissure

is visible from the exterior, but anteriorly is closed by the fusion of the lateral border of the lamina alaris with the auditory capsule, and cranialwards is continued directly into the recessus jugularis. But towards the cavum cranii this cleft enlarges to form the sulcus sigmoideus, in which the sinus sigmoideus runs forwards in order to appear in the region of the recessus jugularis as the jugular vein. The whole fissure is thus only visible from the cavum cranii on removal of the sinus sigmoideus (Pls. 5, 8). The infero-medial surface is triangular in shape, the base of the triangle being anterior. Laterally it is bounded by the prominentia semicircularis posterior, and medially by the prominentia cruris communis, and more anteriorly on the medial side by the prominentia utriculo-ampullaris inferior. Immediately medial to its lateral boundary a fossa is met with, which perhaps deepest posteriorly may with Voit be termed the *fossa subarcuata posterior*. It is formed at the expense of the under aspect of the massa angularis; medial to the fossa subarcuata posterior the inferior surface is slightly hollowed out by the sinus sigmoideus. The basal region of the inferio-medial surface is slightly convex from side to side, and corresponds with the terminal part of the posterior semicircular canal and its ampulla, and the 9th, 10th, and 11th nerves lie beneath it here, as well as the terminal part of the sinus sigmoideus.

The basal region of the pars canalicularis is partly free and partly continuous with the pars cochlearis of the auditory capsule (Pls. 3, 6, 7). The free part lies medial to the basal boundary of the lateral surface of the pars canalicularis. The free part mainly looks forwards, and from above downwards shows first the forward continuation of the *tegmen tympani* (Pls. 3, 6), whose under surface and root are hollowed out to form the *epitympanic* recess, in which the body and posterior process of the incus cartilage are to a large extent lodged. This fossa deepens inferiorly on the upper aspect of the crista parotica to form the *fossa incudis*, in which lies the pointed posterior end of the short or posterior process of the incus cartilage. Immediately medial to the epitympanic recess and fossa incudis lies the *sulcus facialis* (Pl. 6), in which the facial nerve in its downward and backward course lies. This sulcus is continued downwards and backwards deep to the *crista parotica*, where it still lodges the facial nerve but also the *musculus stapedii*, and when the facial nerve turns forwards out of the primary stylomastoid foramen, the sulcus, now entirely occupied by the stapedius muscle, ends at the *incisura musculi stapedii* (Pl. 6) in the basal border of the lateral surface.

The remainder of the basal surface of the pars canalicularis is continued directly into the pars cochlearis of the auditory capsule. The pars cochlearis (Pls. 1, 2, 3, 5, 6, 7) is a dome-like structure whose general

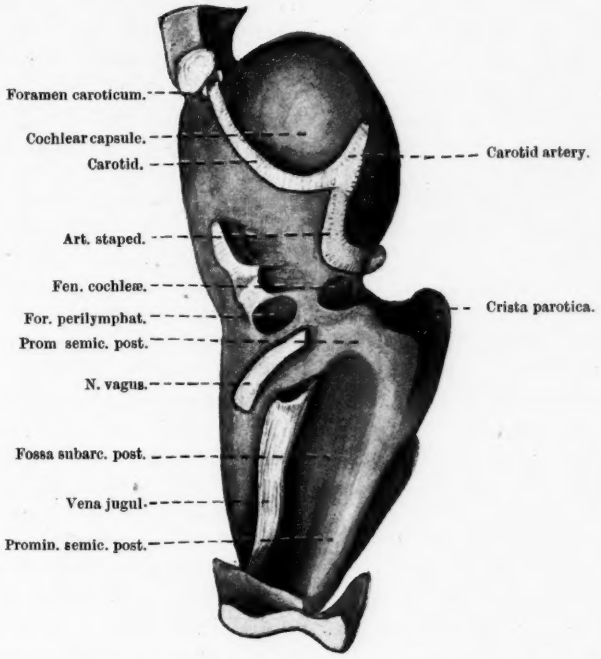
direction is forwards and medianwards, and its apex or *cupula* ends just below and lateral to the carotid foramen. It contains the cochlear duct and the saccule, and may be divided into two parts, a hinder and a fore part. The hinder part is characterised by the presence of a number of openings, viz. on the lateral aspect the *fenestra vestibuli* (Pl. 6), on the infero-lateral aspect the *fenestra cochleæ* (rotunda) (Pl. 6), and on the infero-medial aspect the *foramen perilymphaticum*. On the median wall, at the bottom of the meatus auditorius internus (Pl. 5), the openings for the divisions of the auditory nerve are met with. This hinder part into which these various openings lead may with Voit be termed the "vestibular" segment of the pars cochlearis.

The lateral wall of the vestibular segment (Pl. 6) bears the large oval fenestra vestibuli which lodges the foot of the stapes. Above the fenestra vestibuli the lateral wall of the vestibular segment is grooved by the stapedial artery and the facial nerve (Pl. 6), the former lying more anteriorly. Below the fenestra is the hinder part of the *promontorium* (Pl. 6), caused by the first turn of the cochlea; and below this, at its hinder end, the fenestra tympani (cochleæ) is met with—but that will be referred to again in connection with the inferior surface of the vestibular segment of the pars cochlearis.

The inferior or ventral surface of the vestibular segment of the pars cochlearis is convex and wide from side to side. It is perforated by two foramina, of which the more lateral is the fenestra tympani (cochleæ) and the more medial the foramen perilymphaticum (aquæductus cochleæ). The fenestra tympani (cochleæ) is closed by a thin membrane, the secondary tympanic membrane, and it is separated from the foramen perilymphaticum by a bar of cartilage, under which are placed the jugular sinus and the root ganglion of the vagus, from which starts here to run outwards and upwards the auricular branch of that nerve. The foramen perilymphaticum, which is directed somewhat medially as well as inferiorly, transmits the saccus perilymphaticus and a vein which opens into the jugular vein. This complete separation of the foramen perilymphaticum from the fenestra cochleæ (foramen rotundum) is perhaps in Microtus a precocious condition, for I have not observed it at what may be assumed to be the corresponding period in any other mammal. The ductus perilymphaticus, after leaving the interior of the auditory capsule in the manner aforesaid, runs medially and opens into the subdural lymph space. Its interior is intersected with fine connective-tissue strands.

Passing now to the cochlear segment of the pars cochlearis, we see on its lateral surface (Pl. 6), from below upwards, first the prominentia cochlearis inferior, caused by the first turn of the cochlea. This is crossed

at right angles in its hinder part immediately below the foramen vestibuli (ovale) by a sulcus for the stapedial artery, which in Microtus is of very large size, larger in fact than the internal carotid. Above the promontory and running downwards and forwards from the foramen vestibuli is a sulcus, the *sulcus septalis*, which corresponds with the septum spirale



TEXT-FIG. 2.—Inferior aspect of right auditory capsule of Microtus, viewed from below.

of the interior of the cochlea. Above this sulcus is the prominentia cochlearis superior, caused by the second turn of the cochlea.

The upper surface of the cochlea (Pls. 5, 7) is comparatively small. It is connected anteriorly with the processus alaris of the trabecular part of the central stem by the anterior trabeculo-cochlear commissure, lateral to which lies a longitudinal sulcus which contains the great superficial petrosal nerve, and which broadens posteriorly to form the sulcus ganglion geniculi; more laterally there is a flattened area for the tensor tympani muscle (Pl. 6). To the lateral side of this appears a well-marked band or ridge of dense

fibrous tissue, which reaches outwards almost to the goniale, and most likely represents the forerunner of the processus cochleariformis.

The medial surface of the pars cochlearis (Pls. 5, 7) is posteriorly and below continuous with the inferior surface in the neighbourhood of the foramen perilymphaticum; further forwards it is continuous with the upper surface of the central stem. Along the upper aspect of the chordo-cochlear commissure more anteriorly it is again below continuous with the inferior surface of the "cochlear" segment of the pars cochlearis through the basi-cochlear fissure. In front of this fissure the medial surface is continuous through the posterior trabeculo-cochlear commissure with the trabecular region of the central stem, and in front of this it runs into the lateral wall of the carotid foramen. In the hinder vestibular segment of this surface the meatus auditorius internus is met with, which by a septum running from before backwards is divided into two main parts, viz. an upper and a lower (Pls. 5, 7). The upper segment has two foramina in it—one more anterior, the foramen faciale, and one more posterior, the foramen acusticum superius, through which the nerves to the utricle, the ampullæ of the anterior and lateral semicircular canals, as well as the upper nerve to the saccule, run. The *foramen acusticum inferius* is divisible into three parts, viz.: a small opening immediately below the crista falciformis, for the lower nerve to the saccule—the saccule being here, as described by Voit for the rabbit and for man, supplied by two nerves; a larger area for the cochlear nerve; and a small foramen in the hinder wall of the lower half of the meatus auditorius internus—the *foramen singulare*, through which the nerve to the ampulla of the posterior semicircular canal runs. The upper anterior wall of the meatus auditorius internus is formed by the *suprafacial commissure* (Pls. 5, 7), a cartilaginous bridge which runs from the cochlear part of the pars cochlearis to the vestibular part of the same region, and develops as a spur from the cochlear segment to grow backwards and outwards over the facial nerve and fuse with the vestibular segment over the foramen acusticum superius. Before concluding the description of the meatus auditorius internus it may be said that the saccule lies on the lateral side of the crista falciformis.

No foramen faciale externum vel secundarium, such as is described by Voit, exists at this stage in Microtus, but it is quite possible that it may be present at a later stage, for the appearances suggest it.

The Interior of the Auditory Capsule (Pl. 8).—This, like the exterior, is divisible into a pars anterior and a pars posterior, of which the former is subdivisible into the cavum vestibulare and the cavum cochleare; whilst the latter is divided into the cavum utriculo-ampullare and the spaces for the semicircular canals, including the crus commune.

The cavum vestibulare fills the whole of the vestibular segment of the cochlear capsule and receives the openings of the foramina acustica, fenestra vestibuli, and the foramen perilymphaticum (aquæductus cochleæ) and the foramen rotundum.

The posterior wall of the aquæductus cochleæ is bent upwards into the interior of the cavity so as to form a sort of septum, which lies anterior to the cavum utriculo-ampullaris inferius and shuts it partially off from the main cavity. The medial border, too, of the aquæductus cochleæ is bent upwards and later outwards into the main cavity, so that it forms a small roof to the saccus perilymphaticus. This roof perhaps more strictly belongs to the crista falciformis, which is bent out at its lower margin to form a well-marked ridge in the cavum, which may be traced back along the lateral side of the foramen singulare (canal for nerve to ampulla of posterior semicircular canal), and which may be traced forwards to direct continuity with the septum spirale, a small foramen, for the nerve to the lower part of the saccule, slightly interrupting that continuity. The septum spirale from this junctional point sweeps upwards along the roof, then forwards and downwards along the lateral wall, and finally inwards along the floor of the pars cochlearis, where it dies away. It separates partially the cavity of the first turn of the cochlea from that of the second turn. As has been before stated, the saccule rests against that surface of the crista falciformis directed towards the cavum vestibulare, and above and behind the saccular fossa (fovea saccularis or spherica) and in the same horizontal line with the foramen acusticum superius is the fovea utricularis or elliptica for the upper part of the utricle. On the lateral wall of the cavum vestibulare, almost opposite the outbent lower margin of the crista falciformis, a small groove is found on the upper surface of the inwardly projected upper margin of the foramen cochleæ. This groove lodges the hinder part and blind end of the cochlear duct. The subdivisions of the cochlear cartilaginous tube are not sufficiently well defined at this stage to warrant description, but the hinder part of the scala tympani (the cavum perilymphaticum tympanicum) can be followed back to the aquæductus cochleæ as the saccus perilymphaticus, and thence through the foramen to the subdural space, as already described. In all cases the parts of the membranous labyrinth are separated from the cartilaginous wall of the cavum vestibulare by soft connective tissue of very loose texture, and the membranous semicircular canals lie always near the convexity of the corresponding cartilaginous canals. As a point of accuracy one may say that the prominences designated utriculo-ampullaris are not really caused anywhere by the utricle, but actually in each case by the corresponding ampulla, together with the adjacent part of the corresponding semicircular canal.

(*c*) *The Ala temporalis* (Pls. 1, 2, 3, 5, 9).

This exceedingly interesting structure projects laterally from the middle of the anterior aspect of the anterior trabeculo-cochlear commissure and soon afterwards divides into three processes, of which one, a *median* process, projects downwards and inwards under the anterior trabeculo-cochlear commissure and comes into contact with the cartilaginous part of the pterygoid (Pl. 9), and at this stage this medial process is surrounded by perichondrial bone. The remainder of the ala temporalis runs outwards into the large spheno-parietal foramen and partly breaks it up into an anterior and a posterior segment (Pls. 2, 9), of which the anterior segment persists as the superior orbital fissure (sphenoidal fissure), whilst the posterior—the representative of the fenestra pro-otica of the reptile—becomes gradually obliterated by the conversion of the membranous tissue closing it into bone belonging to the hinder part of the ala temporalis. This outwardly running part of the ala temporalis is slightly concave on its upper aspect, where it lodges the under surface of the semilunar (Gasserian) ganglion. It terminates by turning somewhat sharply upwards and dividing into two branches, of which the hinder and smaller is placed behind the mandibular division of the fifth cranial nerve and is tipped with ectochondral bone; the more anterior and much larger branch, which perhaps may be looked upon as the processus ascendens of the ala temporalis of other quadrupeds, is split by a fissure into two parts, between which the forward continuation of the stapedial artery enters the cavum cranii. This processus ascendens is not continued up so far as the orbito-parietal commissure, as was shown to be the case and so figured by Broom (*Proceed. Linn. Soc. N.S.W.*, 1902) in Dasyurus viverrinus, but stops at some distance from it, and its place is taken by the bony alisphenoid, which has ossified ectochondrally for the most part.

The relations of the ala temporalis to neighbouring structures are of some interest. On its upper aspect lies the Gasserian ganglion, together with the first and second divisions of the fifth nerve; the mandibular division of that nerve passes through the notch between the two branches into which the horizontal part of the ala divides, the notch then being homologous with the foramen ovale; and in this connection it is interesting to note that of the three main branches of the fifth nerve only the mandibular in any sense perforates the ala temporalis either at a notch or a foramen.

Thus it is only, so far as my series go, in Carnivora and in man (? other Primates) that the maxillary division perforates the cartilage of the ala temporalis through a foramen rotundum for that purpose. In all others

that I have had the opportunity of examining, *e.g.* Dasyurus, Tatusia, Talpa, Erinaceus, Crocidura, Lepus, Bos, Ovis, Cavia, Miniopterus, a foramen rotundum is absent,[1] and the mandibular nerve either passes through a notch behind the horizontal part of the ala temporalis or on its lateral aspect, or through a foramen ovale (as in Bos and Ovis). So far as muscles are concerned, in Microtus from the under aspect of the horizontal part as far outwards as the notch for the mandibular division of the fifth nerve the pterygoideus internus arises, whilst from the processus ascendens cartilaginous as well as ossified part the pterygoideus externus arises. It has already been stated that the forward continuation of the stapedial artery passes through the fissure in the processus ascendens.

Mode of Development of the Ala temporalis.

So far as this could be determined from the material at hand, the ala temporalis seems to chondrify independently, but in Talpa from the first a well-marked outrunner of dense connective tissue seems to project from the trabecula dorso-anterior to and independent of the anterior trabeculo-cochlear commissure, and I have been unable to make out independent chondrification here. It is quite evident, however, in Cavia and Tatusia, Bos and Felis catus, as well as in man; and in man at the 27-mm. stage all the appearances associated with early joint formation are seen—all, in fact, save the actual joint cavity. The whole appearances presented strongly suggest its homology with the palato-quadrate cartilage, as surmised by Broom and supported by Watson,[2] and very strikingly is this view supported by the conditions observed by me in 7-mm. embryos of an unknown species of lizard from India. In man, as I pointed out in this journal, the anterior trabeculo-cochlear commissure, which may or may not actually reach the cochlear capsule (I have sections of 27-mm. human embryos which clearly show this commissure reaching the cochlea, as was seen by Jacoby) chondrifies independently and afterwards ossifies independently. As cartilage it has been called the processus alaris in man, and as bone the lingula, but this independence is possibly a secondary condition. Owing to want of material I am unable to say how the ala temporalis of Microtus arises, nor do I know if a separate ossific centre appears in the anterior trabeculo-cochlear commissure.

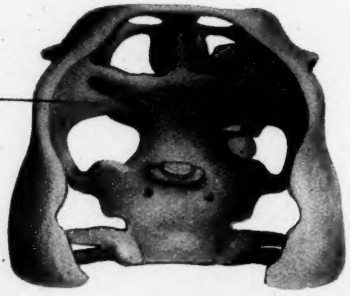
(*d*) *The Ala orbitalis* (Pls. 1, 2, 3, 9).

This structure, which becomes attached to the central stem at the hinder part of the interorbito-nasal septum, not only belongs to the

[1] Miss Esdaile pictures the ala temporalis of *Perameles nasuta* as having a foramen rotundum (*Phil. Trans.*, Series B, vol. 207).

[2] *Phil. Trans.*, Series B, vol. 207.

appendages of that stem, but may be included amongst the lateral structures composing the primordial cranium, and it will be referred to again when these structures are described. It may be described as a large, somewhat triangular plate, whose base enters into the lateral wall of the cavum cranii, whose main mass forms a part of the floor of the cavum, and whose apical region is attached to and fused with the interorbito-nasal septum anterior to the foramen opticum. In mammals belonging to the Eutheria it is usual for the apical or medial region of the ala orbitalis to bifurcate into a limb, tænia præoptica, which passes towards the interorbito-nasal septum anterior to the optic nerve and foramen and fuses with that septum, and a limb which reaches the upper aspect of the ala hypochiasmata behind the optic foramen and so



TEXT-FIG. 3.—Part of chondrocranium of Dasyurus viverrinus, from above. 7-mm. stage.

indirectly is fused with the central stem at the interorbito-nasal septum. This hinder limb is the tænia metoptica, or at all events its representative; but in Microtus, in the specimen modelled and in the "control" specimen not modelled, this hinder limb does not reach the ala hypochiasmata, hence the foramen opticum is not completed posteriorly, and a condition results which recalls that of the Metatheria (Pl. 11), where no foramen opticum is present, the optic nerve passing through the superior orbital fissure (sphenoidal) accompanied by the other nerves destined to the orbit. In Microtus the tænia præoptica is very narrow, as in the mole and hedgehog, and it very closely approaches in form that of Dasyurus viverrinus, in which its mode of growth may very easily be followed, for at the 7-mm. stage its median pointed end is not fused with the interorbito-nasal septum (text-fig. 3), whereas in a stage a little older fusion has taken place. In Tatusia both tæniæ reach the interorbito-nasal septum, but the ala orbitalis lateral to the foramen opticum is perforated

by a foramen of considerable size, though smaller than the foramen opticum, which very much recalls the foramen epiopticum of Lacerta. To return again to the general description of the ala orbitalis. Its posterior border forms the anterior limit of the common spheno-parietal foramen, and at the same time the anterior border of that part of this large foramen in front of the ala temporalis; in other words, the anterior boundary of the superior orbital fissure (sphenoidal). The anterior border of the ala orbitalis is directed towards the nasal capsule, from whose posterior wall it is separated by the *orbito-nasal or ethmoidal fissure* (Pls. 1, 2, 3), through which the nasal (ethmoidal) nerve re-enters the cavum cranii. The outer end or base of the ala orbitalis has two basal angles, of which the anterior is prolonged forwards to meet and fuse with a like but backwardly growing process from the frontal prominence of the pars intermedia of the lateral wall of the nasal capsule (Pl. 3), and the result of fusion is the *commissura spheno-ethmoidalis* (Pl. 3). The mode of growth of the spheno-ethmoidal commissure may be observed in Bos, for at the 19-mm. stage both the anterior basal process of the ala orbitalis and the process from the frontal prominence of the nasal capsule are separate from one another, but at the 25-mm. stage they have fused. In Ovis, according to Dursy—and I can confirm his observation on the specimens I have,—the two do not fuse, at all events in the stages I have sectioned; but it is the general rule to have a complete spheno-ethmoidal commissure, and it may be of large size. The posterior basal angle of the ala temporalis of Microtus is prolonged backwards as the orbito-parietal commissure to fuse with the parietal plate (Pls. 1, 3, 5, 7) which is developed in connection with the pars canalicularis of the auditory capsule; but where one ends and the other begins in Microtus I know not. In Tatusia the greater part of this orbito-parietal commissure grows forwards from the parietal plate, as may be seen at the 12-mm. stage, where fusion has not taken place between the parietal and orbital elements of the commissure.

(*e*) *The Lateral Nasal Capsule.*

This, though being appended to the central stem, will be considered after in the special section dealing with the nasal capsule. We may therefore at once enter upon the consideration of the lateral structures, *i.e.* those structures which enter more especially into the constitution of the lateral wall of the cavum cranii.

3. Lateral Structures.

Under this heading fall the ala orbitalis, the parietal plate, and the supraoccipital cartilage, and incidentally the commissures which bind them together, though these last fall under heading 5 of the original scheme.

The Ala orbitalis has already been fully described, so that no more may be said than that only the basal part enters into the lateral wall of the cavum.

The Parietal Plate (Pls. 3, 5, 7) is that plate of cartilage which extends upwards and forwards from the prominentia utriculo-ampullaris anterior of the pars canalicularis of the auditory capsule. It passes forwards, forming the upper boundary of the large spheno-parietal foramen, to join the posterior basal angle of the ala orbitalis. But where the actual developmental point of junction takes place is not ascertainable from the specimen or model at this age. The part arching forwards from the site of origin may be looked upon as the orbito-parietal commissure, or perhaps the whole structure leading back from the ala orbitalis to the auditory capsule might be given that name. In man no orbito-parietal commissure is formed at all, and the plate projecting from the auditory capsule is then easily termed parietal plate. Chondrification appears to take place somewhat later here than in the ala orbitalis. The inferior margin of the orbito-parietal commissure immediately over the tympanic region of the auditory capsule is arched upwards and outwards as the tegmen tympani (Pl. 3). The posterior margin of the orbito-parietal commissure (or parietal plate) is fused with the supraoccipital cartilage, helping to form the so-called tectum synoticum; but at its lower edge forms the anterior boundary of the superior occipito-capsular fissure, through which, at this spot, the lateral jugular vein runs out of the cavum cranii.

The Supraoccipital Cartilage (Pl. 3).—This structure, by joining its fellow in the middle line over the cavum cranii, forms the so-called tectum synoticum. If it develop along the same lines as it does in the calf, it must be regarded as being of large size in Microtus. It may be said to commence below, opposite the cupula posterior of the auditory capsule (Pl. 3), and is here, in common with the upper end of the exoccipital cartilage (with which it is directly fused), fused with that cupula. It spreads upwards, then divides into an anterior and a median or posterior limb. The anterior limb, which greatly increases in depth as it is traced forwards, arches over the dorsal border of the pars canalicularis of the auditory capsule, from which it is separated by the superior occipito-capsular fissure (Pl. 3), and fuses with the parietal plate or hind end of the orbito-parietal commissure

along an imaginary line drawn vertically through the anterior border of the superior occipito-capsular fissure. Its inferior free margin is prolonged downwards as an *operculum* (Pl. 3) over the upper third of the lateral surface of the pars canalicularis, concealing from view from the outside the prominentia semicircularis anterior and the upper part of the prominentia fossæ subarcuatæ anterior as well as part of the lateral sinus. The free under margin of the operculum affords attachment to muscles reaching the shoulder girdle. The median or posterior process arches backwards and medianwards over the cavum cranii, forming a small part of the upper margin of the foramen magnum, at the incisura posterior thereof, and joins its fellow in the mid-line; the conjoined structures of the two sides forming the so-called tectum synoticum or tectum posterius (Pl. 1), perched on the upper edge of which on each side of the middle line is a small interparietal membrane bone (Pls. 1, 4). In adopting this method of description I have been guided by what happens in the calf at 19 mm. and later at 25 mm.; further, too, by the appearances in the hedgehog of 25 mm. The terminology is not quite satisfactory, since primarily the tectum synoticum has nothing whatever to do with the auditory capsule, and the term tectum posterius is not quite satisfactory, because in man at the 30-mm. and perhaps some later stages there are two tecta here—one a large one which corresponds with that usually called tectum posterius, and which, as I showed some years ago, gave off a processus ascendens in the mid-line; the other is very narrow from before backwards and of considerable width from side to side, but unconnected with any other cartilage. This second cartilage was described by Bolk and confirmed by me *loc. cit.* Gaupp, perhaps rightly, regards this region of the chondrocranium as being in a progressive condition. On the whole, from what has been said, Parker's original name "supraoccipital cartilage" seems the best name to adopt, more especially as that bone is developed from a considerable part of it.

The Lateral Commissures (Pl. 3).—These are from before backwards, the spheno-ethmoidal connecting the frontal prominence of the pars intermedia of nasal capsule with the anterior basal angle of the ala orbitalis, and it has been shown that it is formed equally from both, and is present in all examined save the sheep.

The orbito- or spheno-parietal commissure (Pl. 3), in the light of what has already been said, may be regarded as stretching from the posterior basal angle of the ala orbitalis to the anterior half of the upper margin of the pars canalicularis of the auditory capsule. It is to be regarded essentially as primarily a support for the temporal muscle. It forms the upper boundary of the spheno-parietal foramen.

The Occipito-capsular Commissure (Pl. 3).—This term, perhaps, may

be introduced to imply that part of the anterior process of the supraoccipital cartilage which fuses with the hind margin of the parietal plate or spheno-parietal commissure. Its mode of origin is well seen in the calf at 25 mm.

The Nasal Capsule.

This, rightly described by Voit as an extremely complicated structure, in Microtus is of great size and length: at the stage modelled its length is about one-third of the total length of the primordial cranium (Pls. 1, 2, 3, 9, 10). It forms a striking contrast to that of man, which is very short; but in man what the nasal capsule has lost in length it has gained in height. The nasal capsule consists of a central stem and of two lateral appendages. The central stem or septum is the direct forward continuation at this stage of the central stem of the primordial cranium, and at younger stages of the interorbito-nasal part of that stem (Pls. 1, 2, 9).

The septum nasi has already been described along with the central stem; it will therefore only be referred to from time to time as necessity demands, and we may proceed directly to the examination of the appendages, which form a roof, lateral wall, and floor to the right and left narial passages. Of these parts the lateral wall is the most complete, the roof next so, and the floor most incomplete. The lateral wall may be regarded as quite complete; the roof, however, at its hinder part is perforated by the numerous *foramina cribrosa* (Pls. 1, 9, 10), and in front of these by the small *foramen epiphaniale* (Pl. 1) on each side. At the junction of the roof and lateral wall near the anterior end of the nasal capsule a series of small *fenestra dorsalia* (Pl. 3) is found. The capsule opens out anteriorly on each side of the septum at the *fenestra narina* (Pl. 2), whilst the floor shows a long antero-posterior vacuity, the *fenestra basalis* (Pl. 2); further, between the septum and the paraseptal cartilage on each side is a narrow fissure which has already been alluded to as the *septo-paraseptal fissure* (Pl. 2).

The whole nasal capsule is connected in the middle line with the remainder of the chondrocranium by means of the central stem (septum nasi), and dorso-laterally by means of the spheno-ethmoidal commissures with the corresponding anterior angle of the ala orbitalis (Pls. 1, 3). The hinder third or so of the capsule lies under the brain in the recent condition, and is therefore subcerebral; the remainder is præcerebral.

We may examine the capsule in the first place from the exterior, then from the interior, after dissection of the model.

Of the exterior we have to study the roof or tectum nasi, the lateral wall or paries nasi, and the floor or solum nasi.

The Tectum nasi (Pl. 1) clearly consists of a hinder, much perforated, subcerebral part forming roughly one-third of the whole, and an anterior præcerebral part which is practically complete. The two are inclined at an angle with one another: thus the subcerebral part looks upwards and backwards, whereas the præcerebral part slopes gently downwards and forwards.

The hinder or *subcerebral part* is almost entirely formed by the two cribriform plates or *laminæ cribrosæ*, separated from one another by the *septum nasi* and its *crista galli*, but behind this the tectum is complete where it forms the root of the hindmost part of the pars posterior of the capsule, of which more will be said later. Each lamina cribrosa is triangular in shape, the base of the triangle being at the septum, the shorter side antero-lateral, and the longer one postero-lateral. The antero-lateral boundary is more prominent than the postero-lateral one, and can be traced from the root of the crista galli to the spheno-ethmoidal commissure. The postero-lateral border forms at the same time the anterior or lower border of the orbito-nasal fissure. In this border a slight notch is noticed which indicates the upper end of the postero-lateral sulcus of the paries nasi, to be later described (Pl. 3). This notch also marks the commencement of a crest, the *crista intercribrosa*, which runs obliquely from behind forwards and inwards across the lamina cribrosa, and so divides the *foramina cribrosa* into an antero-lateral and a postero-median group. Through the antero-lateral group the bundle of olfactory nerves from the pars intermedia of the nasal capsule runs to the olfactory bulb, whilst the postero-median foramina transmit the nerves from the pars posterior, the septum, and the organ of Jacobson, the latter especially passing through the most anterior of the foramina by the side of the septum nasi. At the anterior basal angle of the lamina cribrosa, and just lateral to the cribro-ethmoidal crest, a separate foramen, the foramen cribro-ethmoidale (Pl. 1), is found through which the nasal (ethmoidal) nerve leaves the cavum cranii to enter the nasal cavity.

The roof of the præcerebral part of the nasal capsule (Pl. 1) descends gradually. As it is traced forwards from the region of the lamina cribrosa it is continuously blended with the dorsal border of the septum nasi, which, save at a spot just in front of the crista galli, is slightly sunk in a dorsal median sulcus. In its hinder part the tectum passes almost insensibly into the paries nasi of the pars intermedia, but more anteriorly at the pars anterior the passage into paries nasi is much more abrupt, and between the tectum and the intermediate part of the paries nasi a small foramen, the foramen epiphaniale, for the transmission of the lateral branch of the nasal (ethmoidal) nerve, is seen (Pl. 1). From this foramen a slight furrow runs forwards to reach the upper end of the well-marked

sulcus antero-lateralis (Pls. 1, 3), which marks the separation of the pars intermedia from the pars anterior of the paries nasi, and which forms an important landmark as coinciding with the site of attachment of the upper limb of the crista semicircularis of the interior. At its anterior end the tectum nasi bends over on each side to form the *cartilago cupularis* (Pls. 2, 3), which ends below in a small spinous projection, the *processus alaris superior* (Pl. 3), behind which the naso-lacrimal duct (Pl. 3) becomes confluent with the mucous membrane of the nasal sac.

The Lateral Wall of the Nasal Capsule.—Paries nasi (Pl. 3) may be divided into three parts, *i.e.* a pars posterior, a pars intermedia, and a pars anterior.

The Pars posterior is the smallest of all, and is separated from the pars intermedia by the *postero-lateral sulcus*, a curved sulcus which, commencing above at the notch above mentioned as seen in the postero-lateral border of the lamina cribrosa, descends, curving forwards and downwards, behind the pars intermedia to reach the lower border of the paries nasi; it coincides in the interior with the line of attachment of the first ethmo-turbinal. From this aspect the pars posterior presents a somewhat triangular outline whose base is forwards at the postero-lateral sulcus, whose apex (at the cupula nasi posterior) is jammed somewhat tightly against the antero-inferior aspect of the tænia præoptica of the ala orbitalis. Its upper side, which is directed upwards as well as backwards and is confluent at a rounded margin with the postero-lateral border of the lamina cribrosa—and marked, as before said, by a notch, the upper end of the postero-lateral sulcus,—forms the anterior boundary of the orbito-nasal fissure, through which passes the nasal nerve into the cavum cranii. Its lower border is rounded and continued partly into the floor of the cupula nasi posterior and partly into the lamina transversalis posterior, which forms the greater part of the floor of the pars posterior, but will be described later. This lateral surface of the pars posterior is flattened or even hollowed out by the pressure of the contents of the orbit, and the greater part of it frequently goes by the name *planum ant. orbitale*—an area which, however, is not confined to the pars posterior, for, as we shall see, it is continued on to the pars intermedia. But the pars posterior really has in addition a posterior surface which, when traced medialwards, runs directly to the interorbital septum; it is partly tilted forwards, and forms part of a posterior tectum nasi, which has already been mentioned. Here the lateral nasal capsule is directly fused with the nasal septum, but whether this is a primary or a secondary condition I do not know.

The Pars intermedia (Pls. 1, 2, 3) projects more than any part of the

paries nasi away from the nasal septum. It is limited both in front and behind by a sulcus. The sulcus in front, known as the *sulcus antero-lateralis*, separates it from the pars anterior, whilst the sulcus lateralis posterior separates it from the pars posterior. On closer inspection this greatly prominent pars intermedia is seen to be made up of three smaller prominences, which may be named, with Voit, the *prominentia superior*, the *prominentia inferior*, and the *prominentia anterior*. Each of these prominences corresponds with a hollow in the interior of the capsule (Pl. 10); thus the prominentia superior corresponds with the *recessus frontalis*, and might be called the *prominentia frontalis* additionally, because it is covered by the frontal bone. The prominentia inferior is caused by the *recessus maxillaris*, and covered by the maxilla, and therefore might be called the *prominentia maxillaris*. Faint sulci separate these various prominences from one another. The frontal prominence always gives attachment to the spheno-ethmoidal commissure. The maxillary prominence is covered to a large extent by the frontal process of the maxilla, and is crossed at first horizontally, then vertically, by the naso-lacrimal duct, and to its hinder surface and a little below its middle the musculus obliquus inferior is always attached.

The prominentia anterior, which projects forwards at the point of meeting of the maxillary and frontal prominences, is caused by the hollow marking the junction of the recessus maxillaris and frontalis on the internal aspect of the lateral wall of the nasal capsule. It is covered in front by the upper end of the frontal process of the os incisivum. The under margin of the pars intermedia is inrolled, and more posteriorly is directly continuous with the *lamina transversalis posterior* (Pls. 2, 9, 10), whilst more anteriorly it forms a floor to the recessus maxillaris, and more anteriorly still a floor to the *recessus glandularis*, just as in the rabbit as described by Voit.

The Pars anterior (Pls. 1, 2, 3).—This is the longest division of the paries nasi. It is separated, as has been before stated, from the pars intermedia by the antero-lateral sulcus, a sulcus which, commencing just in front of the foramen epiphaniale, arches downwards and forwards in front of and somewhat medial to the prominentia anterior of the pars intermedia, below which prominence it tends to bifurcate into two secondary sulci, of which one, the more posterior, contours the front of the prominentia maxillaris and is almost vertical, whilst the other runs obliquely downwards and forwards to end at about the middle of the lower border of the pars anterior. Between these two limbs a somewhat flattened triangular area exists which is the outer surface of a lamina of cartilage projecting downwards below the level of the maxillo-turbinal (which projects into the interior), and is

consequently called the *lamina infraconchalis* (Pl. 3). Across the lateral surface of the lamina supraconchalis a sulcus runs which lodges the middle part of the naso-lacrimal duct, and which may therefore be named the naso-lacrimal sulcus. Above the level of the lamina infraconchalis a horizontal projection is met with which corresponds to the hollow in the interior which lies above the maxillary concha. The above-mentioned parts belong to the hinder half of the pars anterior of the paries nasi. The anterior half of the pars anterior of the paries nasi is not so deep as the posterior half, and it is marked about midway between its upper and lower margins by several small foramina which perhaps correspond with the fenestra superior of the rabbit, but do not correspond in position with the duct of the lateral nasal gland which lies against the internal aspect of the lateral wall of the nasal capsule. Of these foramina the most anterior is only separated from the fenestra narina by a very narrow bridge of cartilage. Directly below the most anterior fenestra (Pl. 3) the lower margin of this region passes into the lamina transversalis anterior (Pls. 2, 3, and fig. 1), which connects the paries nasi directly with the septum nasi, no fissure existing between the lamina in question and the septum, as in the rabbit according to Voit; there is thus in Microtus a true *zona annularis*.

The inferior margin of the anterior half of the pars anterior may be described as consisting of three parts, viz. a hinder main part which is continuous with the anterior end of the lower margin of the lamina infraconchalis, and at the same time with the anterior end of the maxilloturbinal. It arches upwards and then downwards, and in the recent condition is hidden from external view by an outpouching of the mucous nasal sac, along whose outer edge lies the naso-lacrimal duct after leaving the sulcus on the lamina infraconchalis. When this part of the nasal sac is removed there are exposed to view from the exterior the lower part of the septum nasi and the bilaminar part of the paraseptal cartilage (Pl. 3). As the lower margin is traced forwards it is found to join at an acute angle —the *incisura post-transversalis* (Pls. 2, 3)—the hinder edge of the lamina transversalis anterior. Then, as above mentioned, the lower border is continued into the lamina transversalis anterior, a slight sulcus, in which the naso-lacrimal duct rests, marking the point of junction of the two. In front of the lamina transversalis anterior the inferior border of the pars anterior is free, and a deep notch is formed in it, the *incisura transversalis anterior* (Pl. 3), at which the terminal part of the naso-lacrimal duct is confluent with the nasal mucous membrane. In front of this notch the inferior border ends at a downwardly directed process, the *processus alaris superior* (Pl. 3), which is formed at the angle of junction of the inferior border of the lateral surface with the lateral border of the fenestra narina.

The Lamina transversalis anterior (Pls. 2, 3) is a plate of cartilage of some considerable size which directly connects the lateral wall of the nasal capsule with the septum nasi, no fissure intervening between it and the septum, such as is described and figured for the rabbit by Voit. A true zona annularis therefore exists in Microtus. The lamina transversalis passes outwards from the septum nasi and then suddenly upwards to join the under margin of the lateral wall of the nasal capsule, and at the point of junction both are turned upwards into the interior of the nose to form a well-marked projection, the atrio-turbinal (Pl. 10); and the sulcus which corresponds with this on the under aspect lodges the naso-lacrimal duct.

The Processus alaris superior (Pls. 3, 10) is of great size, resembling in form that of the mole. Starting out from the junction of the margin of the incisura prætransversalis with the margin of the fenestra narina by a somewhat narrow stalk, it soon deepens, to end above in an angular process and below in a somewhat similar one.

The Fenestra narina anterior (Pls. 2, 3) looks forwards and outwards and is bounded medially and in part anteriorly by an *anterior cupolar cartilage* (Pls. 2, 3, 9) of considerable size, which is continued back medially to the anterior part of the septum nasi, and superiorly and posteriorly is continuous with the tectum nasi.

The fenestra narina is filled at this stage in the complete condition by a solid epithelial plug.

The Floor of the Nasal Capsule (*Solum nasi*) (Pl. 2, fig. 1).—Owing to the large size of the lamina transversalis anterior, the lamina transversalis posterior, and the paraseptal cartilage, the floor of the nasal capsule is unusually complete, but there are vacuities in it; for instance, a long antero-posterior vacuity—the *fenestra basalis*—exists bounded in front by the lamina transversalis anterior, behind by the lamina transversalis posterior, medially by the paraseptal cartilage, and laterally by the lower margin of the paries nasi. The greater part of this vacuity is closed by the palatine processes of the maxilla and palate bones, only the anterior end remaining in continuity with the mouth as the primary choana, which intervenes between the os incisivum and the maxilla. Another vacuity is the *septo-paraseptal fissure*, which intervenes between the paraseptal cartilage and the lamina transversalis posterior laterally and the infero-lateral margin of the septum nasi medially. This fissure in the recent condition is closed above by the connective tissue attaching the upper border of the paraseptal cartilage to the septum, and it is also partly closed by the corresponding lamella of the vomer.

The Paraseptal Cartilage (Pls. 2, 3, 9, fig. 1).—This ontogenetically and perhaps phylogenetically in the mammal is double in origin, consisting of

a large *anterior* part which is usually bilaminar, forming a sort of trough in which the organ of Jacobson rests, and which anteriorly is directly continuous with the lamina transversalis anterior, and a *posterior* which is attached to the lamina transversalis posterior.

At the stage modelled there is a common paraseptal cartilage stretching from the antero-median angle of the lamina transversalis posterior to the hinder border of the lamina transversalis anterior, and in its whole length its upper border is connected with the septum nasi by a band of connective tissue. Tracing from behind forwards the paraseptal cartilage (Pl. 2), one observes that its hinder part is very small and cylindrical in form and that this part is to a large extent surrounded by a bony tube derived from the vomer; suddenly, however, the cartilage enlarges, and becomes bilaminar, consisting of a medial or septal and an inferior lamella (Pl. 3). Of the two the septal is the larger, and between them the main part of the organ of Jacobson is lodged, towards the anterior end of the organ of Jacobson; in point of fact, where the duct of that organ is being developed, the septal and inferior lamellæ unite to form a short tube through which the duct runs in an outward direction to open into the nasal cavity, and beyond this point the inferior lamella is alone continued forwards to join with the lamina transversalis anterior. The anterior unilamellar part of the paraseptal cartilage is covered inferiorly by the body of the os incisivum, whilst the greater part of the inferior surface and part also of the medial surface of the inferior lamella are covered by the palatine process of that bone. The medial lamellæ of the anterior paraseptal cartilages are so closely swung together posteriorly that they are only separated from one another by a narrow vertical fissure, and by the anterior end of the vomer which is insinuated between them at this spot.

The Lamina transversalis posterior (Pls. 2, 9, 10, fig. 1).—This, a large triangular plate, forms almost the entire floor of the subcerebral segment of the nasal capsule (as it does in the rabbit—Voit). The apex of this triangular plate is directed backwards to form the floor of the cupula posterior nasi. Laterally it is continuous with the lower rounded margin of the pars posterior of the paries nasi as well as the lower margin of the hindmost part of the pars intermedia. Medially it is directed towards the septum nasi, but separated from it by a fissure in which lies the corresponding lamella of the vomer, and which is to a certain extent invading it. The medial basal angle of the lamina is directly continuous with the paraseptal cartilage. The under surface of the lamina is almost completely hidden from view from below by the palatine process of the corresponding maxilla.

The Lamina transversalis anterior.—The remaining cartilage which

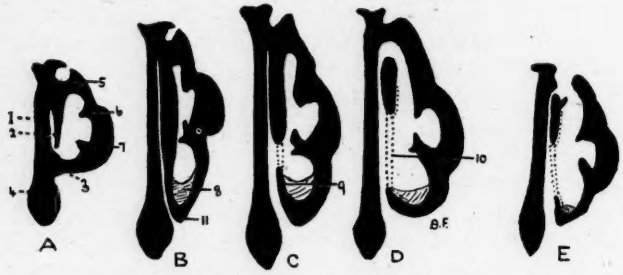
completes the solum nasi has already been described, so that nothing further may be said in that direction.

The whole solum nasi is of great interest phylogenetically as well as ontogenetically. Nothing can be said as to the latter in Microtus, as the necessary stages were not available, but an examination of models of other animals reveals some interesting facts.

In all save man the lamina transversalis anterior exists, and is variable in form with age and species. In Semnopithecus maurus, according to E. Fischer, a small lamina transversalis anterior also exists. In all orders which I have examined the lamina transversalis anterior is in direct continuity with the anterior paraseptal cartilage, until the Carnivora are reached, and here continuity fails in Mustela and Felis catus. In Homo no continuity exists at any time, and this is associated in man with deficiency of the lamina transversalis anterior, so that the fenestra basalis and the fenestra narina are confluent, forming a long fissura rostro-ventralis. In Dasyurus viverrinus the anterior paraseptal cartilage is a long pointed structure reaching along the whole length of the septum nasi almost as far as the posterior wall of the nasal capsule, at the 7-mm. stage. At a little later stage it has fused with this, and as a backward growth of the nasal sac has begun to burrow into the posterior block-like end of the nasal capsule. A lamina transversalis posterior is formed at a still later stage, where a large lamina transversalis posterior is formed, and its medial antero-basal angle is attenuated to form the posterior paraseptal cartilage, which is in direct continuity with the anterior one. In Tatusia novemcincta the anterior paraseptal cartilage alone exists in a procartilaginous condition at the 12-mm. stage, and as a backward projection of the lamina transversalis anterior; but by the 7-mm. stage a posterior paraseptal cartilage has appeared connected in front by fibrous tissue with the anterior one, and behind with the median basal angle of the lamina transversalis posterior, also by fibrous tissue. Whether a complete common paraseptal cartilage ever exists in Tatusia I know not; probably, however, it does not. It is complete in Halmaturus (Seydel), in Dasyurus (Broom and my own observations), in Trichosurus vulpecula (Broom), in Lepus (Voit), and in Microtus, as shown in the model described. When incomplete, the part especially awanting appears to be that formed at the original junctional region between hinder wall of nasal capsule and the anterior paraseptal cartilage.

The lamina transversalis posterior is developed mainly by the thrusting back of the centre of the hinder wall of the capsule by the nasal mucous sac. It may be followed out in all its stages in Dasyurus viverrinus. At the 7-mm. stage it is non-existent; by the 9·5-mm. stage it has just begun to form in the way mentioned; and by the 25-mm. stage, so far has the

posterior wall of the nasal capsule been pushed back that a large triangular lamina transversalis posterior results, and its medial basal angle, which has previously fused with the hinder-pointed end of the anterior paraseptal cartilage, is drawn out to form the slender posterior part of the resulting common paraseptal cartilage. In all the orders and species I have personally examined and modelled, a lamina transversalis posterior exists, although not in the very young stages. It is a comparatively late formation. Its presence is generally denied in Primates and man, but in a model of the chondrocranium of a 65-mm. embryo in my possession a small lamina transversalis posterior is distinctly present, and it is formed precisely as in



TEXT-FIG. 4.—The evolution of the paraseptal cartilages and the lamina transversalis posterior (schematic).

A. The 7-mm. stage in Dasyurus viverrinus.
B. The 9-mm. stage in Dasyurus viverrinus, and in rabbit, water-rat, Trichosurus.
C. Talpa.
D. Ferret, cat.
E. Man.

1, 4, interorbito-nasal septum; 2, anterior paraseptal cartilage; 3, part which, by thrusting back and hollowing out, forms posterior paraseptal cartilage, lamina transversalis posterior, and cupula posterior; 5, lamina transversalis anterior; 6, crista semicircularis; 7, first primary ethmo-turbinal; 8, lamina transversalis posterior; 9, posterior paraseptal cartilage; 10, fibrous internal covering of common paraseptal cartilage persisting after disappearance of cartilage itself; 11, cupula posterior.

other animals. In the schemes illustrated by fig. 4 the various forms are shown.

The Medial Aspect of the Lateral Wall of the Nasal Capsule (Pl. 10).—This, like the lateral aspect, is divisible into three parts, viz. a posterior, an intermediate, and an anterior part.

The Pars posterior or pars ethmoidalis is characterised in the first place by showing a series of parallel projections which project inwards from the lateral wall of this segment and run a course at right angles to the lamina cribrosa. These projections are the primary ethmo-turbinals, or, as sometimes termed, the endo-turbinals. In the passages between the endo-turbinals are small projections, which I term here secondary turbinals, as they develop later than the primary ones; they are the ecto-turbinals of Paulli. At this

stage only one secondary turbinal is developed, and it lies at the bottom of the hollow between the first and second primary turbinals. There, however, is a hint at a second secondary turbinal between the second and third primary ethmo-turbinals. But the more precise description of these turbinals will be undertaken at a later stage, and we may now consider the boundaries of the medial aspect of the pars posterior of the nasal capsule.

Above it is roofed by the lamina cribrosa (cribriform plate) (Pls. 1, 9, 10), and especially by the postero-median division of the plate as previously described. Below it is almost completely floored by the lamina transversalis posterior (Pls. 2, 9, 10). Posteriorly it is bounded by the tectum superius and the cupula posterior nasi. Its anterior limit is formed by the anterior edge of the first primary ethmo-turbinal. This edge consists of an upper and a lower slope of about equal length, the two slopes meeting in front at a prominent spur. The upper slope commences above and behind at the crista intercribrosa; the lower slope commences at the lower border of the lateral wall of the nasal capsule immediately in front of the lateral basal angle of the lamina transversalis posterior.

The Ethmo-turbinals (Pl. 10).—These, for the reason above stated, may be divided into *primary* and *secondary*. They are sometimes called endo- and ecto-turbinalia, or major and minor respectively.

The primary ethmo-turbinals, at this stage at all events, are three in number, and are named from before backwards, first, second, and third; and of these the first is by far the largest, the third the smallest.

The first primary ethmo-turbinal is not only the largest, but is at the same time the most complicated of the turbinals. It springs from the medial aspect of the lateral wall of the nasal capsule by three roots, an upper, a lower, and an anterior, all of which are continuous with one another at a common centre. The upper and lower roots together form a curve convex in front, which corresponds with the sulcus lateralis posterior of the outer aspect of the lateral wall. The third root passes forwards from the point of greatest convexity of the combined upper and lower roots and forms the floor of that part of the pars intermedia which will afterwards be described as the *recessus frontalis*.

Beyond its roots the first primary ethmo-turbinal projects forwards and inwards, hiding from view from the medial aspect a considerable part of the pars intermedia, of which it also forms the posterior wall. It now splits into two lamellæ, viz. an anterior and a posterior, of which the anterior is by far the larger, and which further differs from the posterior in that it is a triangular plate whose apex forms the prominent spur already mentioned. The posterior lamella is straight. Between these two lamella a large hollow exists which leads upwards to a special

foramen for nerves. The first ethmo-turbinal in all young stages of species I have examined is unilamellar, the splitting into two being a later condition, and, according to Peter and Seydel, it may as in man remain single throughout life.

The Second Primary Ethmo-turbinal is separated from the first by a deep recess or meatus. It reaches from the lamina cribrosa above to the point of confluence of the lower root of the first primary turbinal with the lateral basal angle of the lamina transversalis posterior. At the bottom of the meatus, between the first and second primary ethmo-turbinal, the first secondary turbinal is met with; this runs parallel with the two primary ones between which it lies. The meatus in which it lies opens above to the cavum cranii by a special foramen in the cribriform plate.

The third primary ethmo-turbinal is the smallest. It starts from the hinder part of the lamina cribrosa and runs downwards and forwards to end on the medial aspect of the lateral wall at little above and behind the lateral basal angle of the lamina transversalis posterior. Behind this ethmo-turbinal is a passage which may be called the cupolar recess. It leads upwards to a foramen in the lamina cribrosa.

All these cartilaginous processes are covered by thick olfactory mucous membrane, from which nerves may be traced through the postero-median group of foramina cribrosa to the olfactory bulb.

The Pars intermedia.—This at first sight is a large crescentic or perhaps boomerang-shaped recess in the medial aspect of the lateral wall of the nasal capsule. Its convexity is placed forwards. It is bounded posteriorly by the first primary ethmo-turbinal and also to a certain extent medially by the same plate, and it is very nearly cut into two equal parts, an upper and a lower, by the anterior root of the first ethmo-turbinal. Anteriorly it is limited by a curved projection into the interior of the nose, called the *crista semicircularis*, which corresponds on the outer wall of the lateral wall of the nasal capsule with the greater part of the sulcus antero-lateralis. This crista semicircularis forms the common boundary between the pars intermedia and the pars anterior of the median aspect of the lateral wall of the nasal capsule. It commences above confluent with the upper end of the first primary ethmo-turbinal and cribro-ethmoidal crest at the lamina cribrosa. At its commencement it is perforated by the canal for the lateral branch of the nasal nerve, which after its passage through the cribro-ethmoidal foramen runs at first medial to the crista semicircularis as in the rabbit (Voit); then it perforates the crista, reaching its lateral side, after which it leaves the interior of the nasal capsule by running through the foramen epiphaniale. For the greater part of its course the crista semicircularis

runs downwards and forwards more or less parallel with the upper slope of the anterior lamella of the first primary ethmo-turbinal. It then, opposite the spur developed on that lamella, bends sharply downwards in front of the recessus antero-lateralis of the pars intermedia, to end in a faint ridge in the floor of the recessus maxillaris. In this respect it differs here from that in the rabbit, where, according to Voit, it forms a sort of bridge over the lateral wall of a part of the recessus maxillaris (Voit), and is the cartilaginous processus uncinatus. This does not exist in Microtus, though the faint ridge above mentioned may be regarded as its representative.

Turning now to the description of the pars intermedia itself within the boundaries as defined, we may say at once that it is to a large extent hidden from view from the medial aspect by the close approximation of the first primary ethmo-turbinal to the crista semicircularis. Taken as a whole, it is deeply recessed in the outward direction, which recessing causes the great outward projection of the lateral wall of the nasal capsule in this region, and this general recess is subdivisible into a series of smaller recesses. Two of these, viz. an upper or *recessus frontalis* or superior, and a lower, the *recessus maxillaris* or inferior, are almost completely separated from one another by the anterior root of the first primary ethmo-turbinal. Where the said anterior root dies away in front, these two recesses communicate with one another at what is named the *recessus anterior*, which lies under cover (as viewed from the medial aspect) of the crista semicircularis. We have already seen that these recesses produce corresponding prominences on the exterior of the pars intermedia.

The Recessus superior or frontalis (Pl. 10) lies above the anterior and superior roots of the first primary ethmo-turbinal, and under cover to a large extent of the crista semicircularis. It is placed almost at right angles to the recessus inferior or maxillaris, produces the prominentia frontalis on the exterior (Pl. 3), and is subdivided into three secondary recesses, which, however, are not marked on the exterior by two frontal turbinals which, running parallel with one another, are roughly parallel with the upper slope of the anterior lamella of the first primary ethmo-turbinal. Each commences above at the antero-lateral part of the lamina cribrosa, and the more anterior of the two is the larger and more prominent, and reaches as far down as the anterior end of the anterior root of the first primary ethmo-turbinal. The passages or recesses into which the recessus frontalis is broken up each open by a special foramen into the cavum cranii through the antero-lateral segment of the lamina cribrosa (Pls. 1, 10).

The inferior main division of the lateral recess is subdivisible into three parts, viz. the recessus maxillaris proprius, the recessus anterior, and the recessus glandularis.

The Recessus anterior (Pl. 10) is that recess which is at the junction of the upper and lower main subdivisions of the recessus lateralis. It projects deeply forwards under the most forwardly bent part of the crista semicircularis, and causes on the exterior the prominentia anterior, which there is to a large extent hidden from view by the frontal process of the os incisivum.

The Recessus maxillaris (Pl. 10) is the largest of the three subdivisions of the inferior part of the lateral recess. It is considerably overhung from behind by the inferior root of the first primary ethmo-turbinal. Into it from the front enters the lower end (processus uncinatus) of the crista semicircularis. From its lower anterior part may be separated off the *recessus glandularis* (Pl. 10), which lodges the lobules of the lateral nasal gland. This is the lowest and most anterior of the subdivisions of the inferior part of the lateral recess. It is not very distinct, and it is only definable by modelling *in situ* the lobules of the said gland.

The Pars anterior (Pl. 10) of the medial aspect of the lateral wall of the nasal capsule is roughly triangular in form, with its base backwards at the crista semicircularis, which thus forms its posterior boundary. It reaches forwards from this to the tip of the nose. Inferiorly and posteriorly the pars anterior is confluent with the inferior part of the pars intermedia, the site of confluence being the recessus glandularis.

The pars anterior is characterised more particularly by its great antero-posterior length, and by the projection into it of three turbinals, of which perhaps the most striking is the *naso-turbinal*; the others are the *maxillo-turbinal* and the *atrio-turbinal*.

The naso-turbinal extends over quite two-thirds of the whole length of the pars anterior. Commencing at the junction of the anterior and middle thirds, it runs backwards almost midway between the upper and lower limits of this region, and it ends shortly in front of the crista semicircularis by bifurcating into an upper and a lower limb. For a very large part of its extent it is not fused to the lateral wall of the nasal capsule; in fact, fusion only occurs anteriorly and posteriorly. The naso-turbinal may be looked upon as a convex sheet which practically divides the general concavity of the pars anterior into two equal channels, the upper of which is roofed by the tectum nasi, whilst the lower is floored by the maxillo-turbinal. It may be mentioned that, of the two hinder limbs of bifurcation, the upper is the shorter one, and is only bound to the lateral wall by fibrous tissue, whilst the longer lower limb is con-

fluent in its whole length. Between the two limbs is a foramen through which blood-vessels and nerves run.

The Atrio-turbinal (Pl. 10) commences anteriorly as an inrolling of the lateral wall of the incisura narina, which takes place just medial to the foramen superius, and is continued backwards as an invection of the lamina transversalis anterior, corresponding with the sulcus naso-lacrimalis. It comes abruptly to an end near the posterior border of the lamina transversalis anterior, a notch—the *incisura maxillo-atrioturbinalis* (Voit)—separating it from the anterior end of the maxillo-turbinal (Pl. 10). As in the rabbit (Voit), this notch is filled with fibrous tissue, there being no such interruption in the soft parts.

The Maxillo-turbinal (Pl. 10) commences in front, immediately behind the incisura maxillo-atrioturbinalis, as a simple, very slight inrolling of the lower border of the pars anterior, and as such is continued backwards for almost half its extent, and under its convexity one sees the naso-lacrimal duct; further backwards the maxillo-turbinal runs along the upper edge of the lamina infraconchalis, which stands nearly vertically, and when the latter ceases to exist the maxillo-turbinal once more makes itself evident as the inrolled lower margin of the pars intermedia of the nasal capsule; but here, as Voit truly remarks of the rabbit, "da in diesem Gebiete an dem mit Schleimhaut bekleideten Präparat kein Vorsprung zu bemerken ist." But the amount of inrolling seems to be much less than in the rabbit, for the sulcus which lies above it—the sulcus supraconchalis (Pl. 10)—is very little expressed, and posteriorly that sulcus is continued into the recessus glandularis of the pars intermedia, whilst anteriorly it runs out at the incisura narina, having joined in front with the passage in the lateral wall above the naso-turbinal to form a sort of vestibule which laterally is perforated by the foramen superius.

The Naso-lacrimal Duct (Pls. 2, 3).—This, formed by the union of an upper and a lower canaliculus just above the maxillary prominence on the pars intermedia of the *paries nasi*, passes at first horizontally forwards under the prominentia anterior, then rapidly descends, lying below the primordium of the lacrimal bone, which has only to the very slightest extent ossified, and has not been represented in the model. The duct then descends along the front of the maxillary prominence immediately above the maxillary origin of the masseter muscle and, descending between the frontal process of the maxilla and the body of that bone, it comes to lie against the upper edge of the lamina infraconchalis in what I have previously termed the naso-lacrimal sulcus, opposite and above which in the interior of the nose is the lateral nasal gland; here it is surrounded by a vascular plexus, and is covered externally now by the body of the maxilla

and by a somewhat dense sheet of connective tissue. Then, when the lamina infraconchalis dies out in front, the duct lies along the under margin of the paries nasi between that and the socket for the large incisor tooth uncovered in part by bone; next it lies above that outpouching of the nasal sac which projects below the lower margin of the paries nasi, and which is not covered laterally by any cartillage, and, coursing along in the relation just mentioned to the mucous membrane, it reaches the lateral margin of the lamina transversalis anterior, in a groove of which it lies, the groove corresponding with the atrio-turbinal. In this region it is accompanied by a small gland-like structure which opens independently into the interior of the nose and is not in any way connected with the naso-lacrimal duct; now the naso-lacrimal duct sinks into the incisura prætransversalis under cover of the descending process of the processus alaris superior, lying still below the atrio-turbinal, and suddenly ends by communicating with the nasal sac below the atrio-turbinal. At no part of its course was I able to observe any lumen in the duct.

The Nerves of the Olfactory Region.

The nasal (ethmoidal) nerve enters the cavum cranii extradurally through the anterior part of the orbito-nasal fissure lying lateral (dorsal) to that bunch of olfactory nerves coming from the recessus frontalis. After a short course it gives off a lateral branch which, entering a special canal which traverses the root of the crista semicircularis, emerges on the tectum nasi at the foramen epiphaniale and later descends under cover of the nasal bone. The parent trunk passes through the cribro-ethmoidal foramen in company with a few olfactory filaments, and cannot be traced very far in the mucous membrane. It therefore coincides very closely with that of the rabbit, as described by Voit.

The Olfactory Nerves require but little description. They are divisible into three groups of septal, postero-median, and antero-lateral. The septal group includes the large trunks coming from the organ of Jacobson, which run from that organ obliquely upwards and backwards along the septum to enter the cavum cranii by a large slit-like foramen lying by the side of the crista galli; they ultimately enter the median anterior aspect of the olfactory bulb. The antero-lateral group leave the recessus frontalis through the foramina in the antero-lateral region of the lamina cribrosa, and in front of the cribro-ethmoidal crest, and, joining together to form a large bundle, enter the antero-lateral aspect of the olfactory bulb. The postero-median group enter the cavum cranii through the postero-median foramina behind the cribro-ethmoidal crest, and then bend forward—at all events the hindmost of them—to enter the lower and hinder part of the olfactory bulb. The

bulb is hollow, and the hollow communicates posteriorly with the interior of the corresponding lateral ventricle of the brain.

Visceral Skeleton.

The first visceral arch is that formed by Meckel's cartilage, which at its hinder end passes directly into the cartilaginous malleus (Pls. 3, 9). The cartilage of Meckel is of great length, passes from the malleus in a somewhat wavy course inwards and downwards at first, then downwards and outwards; after which, bending once more inwards for a short distance, it runs almost horizontally forwards, converging on its fellow ultimately, to fuse with it and form a double-pointed common anterior extremity. For the greater part of its length it is cylindrical in form, but not far from its anterior extremity, where it is undergoing ossification, it elongates in the vertical direction; and where it is becoming absorbed, which it does to a very large extent when incorporated within the mandible, it assumes a crescentic form, the concavity of the crescent being outwards.

Soon after leaving the malleus cartilage Meckel's cartilage is covered on its lateral side by the antero-superior limb of the tympanic bone (Pl. 5), and in this region too it has below it the flat goniale (prearticulare) (Pls. 5, 6); on its lateral aspect, at a greater distance than the os tympanicum, is that large mass of cartilage which forms the condyle and neck of the mandible (Pls. 3, 9). The cartilage next comes more immediately into relation with the mandible, in a large deep groove (Pl. 9) of which it lies almost buried from view from the medial side. It is overhung here by the inner alveolar wall, which at its hinder end develops an accessory mass of cartilage (Pls. 3, 9); below and to its lateral side is a large accessory cartilage (Pls. 3, 9), which forms the angle of the jaw at this stage; beyond this cartilage Meckel's cartilage sinks entirely into the mandible and remains within it as far as the foramen mentale, beyond which it again emerges on the medial side as far as its termination; on the lateral side of Meckel's cartilage, just before its termination, a small accessory cartilage (Pls. 3, 9) is in relation to it, separating it from the bony mandible, which lies more laterally. But these accessory cartilages will be described later along with the bony mandible, because they have nothing whatever to do with the primordial cartilage of the skull.

The Malleus Cartilage (Pls. 3, 4) is of large size, forming above a head whose upper aspect is practically in continuity with the plane of the upper margin of Meckel's cartilage. This head is overlapped above by the tegmen tympani; posteriorly it is in articulation with the incus; below, it runs into the neck, into whose inner and lower part is inserted the tendon of the tensor tympani muscle (Pl. 6), below and behind which the

chorda tympani nerve runs. Below the insertion of the tensor tympani and on the lateral side a prominent processus brevis is met with (Pl. 3). The manubrium mallei below this passes downwards and forwards, following the line of the sulcus spiralis of the cochlear capsule (Pls. 3, 6).

The Incus Cartilage (Pl. 3) resembles very much the bony incus; it consists of a bony short posterior process which, together with the body, is overhung by the tegmen tympani and its downward continuation the crista parotica. The short process is lodged in a well-marked fossa incudis (Pls. 3, 6). The long process descends not quite parallel with the malleus, and, diverging at an acute angle from it, at the level of the processus brevis articulates with the stapes cartilage (Pls. 3, 6), no joint cavity at this stage intervening between the two.

The Second Visceral Cartilaginous Arch (Pls. 3, 6).—This is only imperfectly represented. Commencing with the stapes, which has the usual form and which is perforated by an enormous stapedial artery, and further has inserted into the posterior aspect of its neck the stapedius muscle, we pass, with a great break, to the stylo-hyal, which is confluent with the crista parotica and descends from this along the front of the pars canalicularis of the auditory capsule almost to the level of the processus paracondyloideus, when, after a slight interruption in continuity in cartilage, it again assumes a comparatively large calibre and bends sharply inwards under the cochlear capsule, then as cartilage it comes to an end opposite the point where the stapedial artery is given off from the internal carotid. It once more reappears at the junction of the thyro-hyal with the basi-hyal as the cerato-hyal. It is separated from both by connective tissue.

The thyroid or third-arch visceral skeleton is represented by an unusually small cartilage not much larger than the cerato-hyal, and it has no connection with the thyroid cartilage (Pl. 3).

The skeleton of the fourth arch, represented by the thyroid cartilage, is of large size; its ala is perforated by a blood-vessel accompanied by the internal laryngeal nerve. Large superior and inferior cornua are present, and an enormous inferior marginal tubercle projects laterally and somewhat downwards from the middle of the inferior margin of the ala.

The skeleton of the fifth arch is represented by the cricoid, which is surmounted in the usual fashion by the arytenoid cartilages.

The epiglottis is represented as a stalked cartilage, whose blade is folded medianly, so that in section it has a somewhat V-shaped appearance. Joint cavities are developed between the arytenoids and the cricoid, but no joint cavity has as yet appeared between the inferior cornua of the ala and the cricoid.

The visceral skeleton as a whole will be dealt with later, in a subsequent

communication. It may suffice to say here that it resembles much that of other Eutheria, and is probably derived from five arches as in Metatheria.

The Osseous Skeleton.

The Covering Bones.—These for the most part are well developed.

Interparietalia.—Commencing behind we note the two interparietalia (Pls. 1, 4), placed near the middle line above the tectum posterius (synoticum), and separated by a considerable interval from the parietalia, as in rabbit; a considerable space exists between the two interparietalia, which is occupied by the fibrous, non-cartilaginous roof of the cavum cranii.

Parietalia (Pl. 4).—Each is of considerable size, narrow behind, broader in front, covering the processus anterior of the supraoccipital cartilage. The upper part of the parietal plate and the hinder part of the orbito-parietal commissure each reaches towards its fellow, but does not meet it, and a considerable fibrous space is left between the two above the limits of the cartilage of the lateral wall of the cranium. A somewhat oblique coronal suture separates the frontal from the parietal bone, whilst the under edge of the parietal in its anterior half or so is overlapped by the upper edge of the squamosal (this is not shown in the model).

The Frontalia (Pls. 1, 4) are larger than the parietalia, with which they come into close contact behind; each covers the greater part of the orbito-parietal commissure, the upper half or so of the ala orbitalis, and anteriorly passes along the spheno-ethmoidal commissure to cover a considerable part of the prominentia frontalis of the nasal capsule, on which the frontale splits into a median and a lateral part, the former of which lies over the tunnel in which is contained the lateral branch of the nasal (ethmoidal) nerve, and which opens out under this median process of the frontal bone at the foramen epiphaniale. Over the orbital fossa a slight ridge is formed on the frontal bone, which divides this part into an upper part (pars frontalis) and a lower part which forms the very oblique bony roof of the orbit (pars orbitalis). This ridge, which is not very well marked anywhere, is the *arcus supraorbitalis* (Pl. 4), and, unlike that of the rabbit, does not develop posteriorly a processus supraorbitalis posterior. Before passing on to the recessus frontalis of the nasal capsule, the anterior part of the frontale forms a roof to the subcentral part of the nasal capsule and so completes the cavum cranii above and in front.

The pars orbitalis projects downwards over the outer side of the upper part of the orbito-ethmoidal fissure. Postero-superiorly the frontale is separated at the upper end of the coronal suture by a wide notch filled by fibrous tissue, which is the homologue of our human bregmatic fontanelle.

The Squamosum (Pl. 4) is a bone of considerable size, which consists of a large squame overlapping the lower and fore part of the parietal plate, and more anteriorly the hinder part of the orbito-parietal commissure. From its posterior end two narrow processes pass backwards, one an upper, which lies to the outer side of the parietal plate and is horizontal in position; the other, the post-auditory process (Pls. 4, 6), crosses the lateral jugular vein superficially, then the upper parts of the malleus and incus cartilages, to reach and cover the junction of tegmen tympani with the crista parotica. In its hindmost part an accessory cartilage is developed. The upper border of the main part of the squama overlaps the lower edge of the parietal, and reaches forwards beyond that bone to the under margin of the frontale. Its anterior margin articulates with the alisphenoid, whilst the lower margin is somewhat complicated. It may be best described as bifurcating into a median and a lateral lamella (Pl. 6), of which the former descends on the lateral aspect of the parietal plate and of the hinder end of the orbito-parietal commissure almost as far as the upper surface of the tegmen tympani as it lies to the medial side of the cartilaginous condyle of the mandible. This median lamella forms the medial part of the glenoid cavity (Pl. 6). The outer lamella of the lower margin of the squama develops as the processus zygomaticus, which, after overlapping on the outer side the cartilaginous condyle of the mandible (Pl. 4), turns forwards almost horizontally as far as the coronoid process of the mandible, where it ends obliquely to support the hind end of the os zygomaticum. Nowhere in the region of the glenoid fossa is any accessory cartilage discoverable, such as is found in man and some other mammals.

The Nasale (Pls. 1, 4) lies on the dorsal aspect of the pars anterior of the nasal capsule, reaching laterally almost as far as the oblique upper anterior edge of the frontal process of the incisivum. Posteriorly it is practically coincident in extent with the frontal process of the incisivum, and, as in the mole as figured by Fischer, it bifurcates into two plates, of which the medial extends further back than the lateral. Anteriorly the nasale does not reach so far as the foramen superius, nor does it cover any of its satellites.

Here and there the two nasalia seem to be united across the middle line, more especially in the anterior part; posteriorly they recede somewhat from one another and the middle line.

The Incisivum (Pls. 1, 2, 4) is a very large bone, its size, as in the rabbit, depending upon the large size of the upper incisor tooth. It lies on the lateral and under aspects of the pars anterior of the nasal capsule, and may be described as consisting of a body, a frontal process, a median and

a lateral palatine process. The body contains a single alveolus for the lateral large incisor tooth, there not being any germ for the median one at this stage. It covers the lamina infraconchalis and the naso-lacrimal duct, as well as the anterior part of the fenestra basalus of the nasal capsule and a considerable part of the paraseptal cartilage, but at this stage at all events does not reach so far forwards as the lamina transversalis anterior, which can be seen freely from the side in front of the medial alveolar wall of the incisor alveolus (Pls. 2, 4). The upper border of the body of the incisivum is separated by a small interval from the nasale, so that part of the nasal capsule is seen between them; and if the anterior border of the body be traced upwards, it will be seen to lie in the same line as the anterior border of the nasale, the two forming the lateral boundary of the bony apertura pisiformis. Beyond this apertura pisiformis the apex of the pars anterior of the nasal capsule is projected for very nearly half its extent, so that, amongst other things, the whole of the lamina transversalis anterior, the anterior end of the incisura post-transversalis, and of the naso-lacrimal duct, as well as the fenestra superius and its satellites, are exposed to view (Pl. 4). The frontal process (Pl. 4) projects obliquely backwards into the gap between the nasale and the maxillare, but does not reach the frontale, a considerable part of the pars intermedia of the nasal capsule being exposed to view between the two (Pl. 4). The lateral palatine process is very massive; it forms the under aspect of the body of the bone and lies underneath the hinder part of the lamina infraconchalis (Pl. 2). Posteriorly it seems to blend with the maxilla, or at all events to be separated by a very fine suture from it. The processus palatinus medialis (Pl. 2) passes backwards along the medial and under aspect of the paraseptal cartilage, and can be traced along it for about half the length of the organ of Jacobson; and almost immediately behind it and somewhat above, the vomer follows in the gap between the two paraseptal cartilages.

The Maxillare (Pls. 1, 2, 4) consists of a body, a frontal process, an outer and an inner alveolar process, a palatine process, and a zygomatic process. The body is of comparatively small size, and is perforated by an enormous infraorbital foramen, through which are exposed to view the maxillary prominence of the pars intermedia of the nasal capsule as well as a part of the naso-lacrimal duct. From the body the large triangular frontal process is continued upwards over the pars intermedia of the nasal capsule in the gap between the frontal process of the incisivum and the frontale, but it is separated by a tolerable interval from the two.

Both the anterior part of the body of the maxillare and its frontal process are curved around the anterior aspect of the pars intermedia towards the antero-lateral sulcus of the nasal capsule.

The inferior surface of the body (Pls. 2, 9) is convex, and posteriorly divides into the two alveolar processes, outer and inner. As this rounded inferior surface is traced inwards it is found to bound laterally the foramen incisivum and at the same time to form the under bony border of the paries nasi. Opposite the middle of the infraorbital foramen the body of the maxillare divides below into two backwardly directed processes, viz. the median and lateral alveolar (Pl. 9); of the two the lateral is much the smaller, but at two spots its line backwards is continued by two isolated masses of bone, one of which is placed opposite the coronoid process of the mandible, the other intervening between the one just mentioned and the hinder end of that part of the lateral alveolar process which is in continuity with the body of the maxilla. The median alveolar process, starting at the same point as the lateral one, is much the larger, and may be traced backwards as far as the hinder third of the palatinum, where it ends in a pointed posterior process. It overlaps on the outer side the angle of the palate bone at the junction of the vertical and horizontal laminæ of that bone.

The palatine process of the maxilla is a horizontal shelf of bone projected towards its fellow of the opposite side, which more anteriorly it almost meets; but more posteriorly it recedes somewhat from its fellow, and it dies away as the palate bone is approached. It forms part of the floor of the ductus naso-pharyngeus. In no part of its length is it in contact with the vomer at this stage, nor is any cartilage developed along its medial border, as is so common in animals.

The zygomatic process of the maxilla projects backwards from the body of the bone opposite the hinder wall of the infraorbital canal, and it stretches away back as far as the zygomaticum, which it meets opposite the anterior border of the coronoid process of the mandible, under whose anterior oblique border it passes for some distance (Pl. 4).

Before leaving the description of the maxilla one may say that, except anteriorly, the premolar and molar teeth have no bony roof to the common alveolus, but they are separated from the orbit by a thin sheet of connective tissue in which afterwards bone is doubtless developed.

Opposite the upper hinder part of the infraorbital foramen, and behind and under cover somewhat of that part of the frontal process of the maxilla, a very small os lacrimale is met with; this, as has previously been mentioned, is of very small size, and lies for the most part above the naso-lacrimal duct. It has not been represented in the model.

The Os zygomaticum (Pl. 4) is a narrow bone pointed at each end; its anterior point passes fowards over the zygomatic process of the maxilla, whilst its posterior process sinks backwards under the anterior extremity

of the zygomatic process of the temporal bone. From its deep side arises the zygomatico-mandibularis muscle.

The Os palatinum (Pls. 2, 9) is a comparatively large bone which commences under the cupula posterior, in close contact with which it lies; it is continued backwards under the trabecular and interorbito-nasal parts of the central stem as far as the front of the ala temporalis. It consists of two lamellæ, one the vertical lamella or plate, which is vastly greater than the other or horizontal plate; and it is this vertical plate that by its upper border comes into contact with cupula nasi, interorbito-nasal (lamina hypochiasmata), and trabecular parts of the central stem. The vertical plate joins at right angles the horizontal plate, and from the angle of junction posteriorly a well-marked tuberosity, such as is seen in man, projects backwards and outwards along the anterior edge of the ala temporalis; medial to the vertical plate and above the horizontal plate the ductus naso-pharyngeus passes backwards. Along the lateral side of the vertical plate lies the comparatively large spheno-palatine ganglion. Along the under aspect of the horizontal plate, and not far from the tuberosity, a well-marked forwardly running groove is seen which is chiefly occupied by a large palatine vein. As one traces the vertical plate further backwards one sees on its lateral side the Gasserian ganglion, and one notices how very closely the bone approaches the floor of the cavum cranii; and in this region too the Vidian nerve lies laterally to the upper end of the vertical plate. The root of the tuberosity comes to lie over the cartilage of the pterygoid bone (parasphenoid of Gaupp), and later in front and to the outer side of the pterygoid bone itself; and at the upper edge of this region the Vidian nerve bends over it from the lateral to the median side, running between the palate bone and the central stem of cartilage, which now is being enclosed by periosteal bone (the primordium of the basi-sphenoid).

The Os pterygoideum (Pls. 2, 9) (*Parasphenoid of Gaupp*).—This interesting bone lies behind and medial to the hinder part of the palate bone; further, it is placed lateral to the hindmost part of the ductus naso-pharyngeus. For the most part it consists of membrane bone, but encloses everywhere, save below, a very large cartilaginous nucleus (Pls. 2, 9), the basis of the hamulus around which the tendon of the tensor palate muscle turns into the soft palate. The contained nucleus in coronal section is pear-shaped in form, with the stalk of the pear reaching up almost to make contact with the pterygoid process of the ala temporalis, only a very thin lamella of bone intervening. The bone which envelops this cartilage from above is fused at this time at its upper end with the post-sphenoidal ossification, and in the angle between the two is seen the Vidian nerve. Lateral to cartilage and bone of the

pterygoid the belly of the tensor tympani may be seen, and the central skin in this region is almost devoid of cartilage, that having been absorbed for the most part.

The Alisphenoid (Pls. 2, 4, 5) is partly a covering and partly a substitution bone—formed mainly in the perichondrium along the anterior edge of the ala temporalis; it also extends along the outer edge of that cartilage as far as the tip of its posterior lateral process. Invading the anterior limb of the fissure in the processus ascendens of the ala temporalis, it on leaving this expands widely as an ossification of the representative of the membrana obturatorum; it comes next to lie over and form a covering bone to the orbito-parietal commissure, along which it reaches anterior to the squama of the os squamosum. It does not, however, at this stage reach by a considerable distance the lower margin of the frontale. Viewed as a whole from the front in the model, the alisphenoid is seen to consist of two limbs—one horizontal, which lies along the anterior border of the ala temporalis, from which the musculus pterygoideus internus arises; the other almost vertical, from which the musculus pterygoideus externus arises. The upper edge of this part is overlapped by the squama of the os squamosum.

The Os tympanicum (Pls. 4, 6), a somewhat horseshoe-shaped membrane or covering bone, open behind, may be described as having two limbs, viz. an upper and a lower, which join just below and lateral to the cupula cochlæ. The upper limb lies below and lateral to the hind end of Meckel's cartilage, and on its medial side the goniale is seen lying below Meckel's cartilage. The lower limb, more cylindrical, follows very much the inferior contour line of the first turn of the cochlæ, from which it is separated by a comparatively small interval. From the close relation of the hinder end of the upper limb of the tympanicum to Meckel's cartilage, it may be looked upon as a covering bone to that cartilage. The manubrium mallei is projected into the middle of the area enclosed by the two limbs of the tympanicum.

The Goniale (Gaupp) or *Prearticulare* (Pls. 5, 6) is a flat membrane bone of some size, placed on the under aspect of the hinder end of Meckel's cartilage, immediately medial to the hind end of the upper limb of the tympanicum, between which it stretches, and the tensor tympani muscle, lying just dorsal to the tympanic cavity. It is perforated from above downwards by the chorda tympani nerve rather nearer its lateral than medial side, and much nearer its posterior extremity than its anterior one. It ends behind in a pointed extremity which is in close contact with the lower aspect of Meckel's cartilage, and its backward extent is somewhat greater than that of the upper limb of the tympanicum. Only a small

part of the bone has much relation to Meckel's cartilage—in fact, little more than its outer edge. The great part of the bone is spread over the cavity of the tympanum (mucous membrane), and it reaches so far towards the tensor tympani muscle as to give one the impression that this muscle has some connection with it. In cross section the goniale in its best-developed part is of wavy outline, thin and concave upwards in its outer half, thick and concave downwards at the inner half, and subtended on its inner side by dense connective tissue in whose concavity the tensor tympani muscle lies.

The Mandibula (Pls. 2, 4, 9).—This, by far the largest bone of the skull, is composed of two symmetrical halves. Each half consists of a body which along a large part of its course divides in the upward direction to form two alveolar laminæ, one medial, the other lateral, which are widely separated from one another, but at this stage no alveolar septa are formed between the teeth contained. Posteriorly the body divides into three branches, of which the middle one, mainly represented by cartilage, passes backwards to the glenoid fossa of the squamosum; another, the ascending branch, is the coronoid process, which passes upwards under cover of the os zygomaticum; whereas the third or remaining process, formed of cartilage, forms the large backwardly divided angular process.

Both the condylar cartilage and the angular one are closely invested by perichondrial bone continuous with the bone belonging to the neighbouring parts of the mandible, but both cartilages, when traced backwards, emerge from this investing bone and become surrounded by a thick covering of dense connective tissue. As the condylar cartilage is traced to its proximal extremity, its cells which are most proximal are seen to be in a much younger condition than the more distal ones, and they ultimately merge into the surrounding fibrous tissue; above this connective tissue a joint cavity is present, and above that a connective-tissue interarticular plate, and above this again another joint cavity is visible. There are no cartilage cells in the interarticular plate or disc, and the external pterygoid muscle is in part inserted into its medial edge.

As has been before mentioned, the main body of the jaw divides into two lamellæ, viz. a median and a lateral; these two are the alveolar processes or walls. The inner alveolar process at its hinder end is fused with the inner side of the root of the coronoid process to form a bridge under which the inferior dental nerve runs from behind to enter the common alveolus. At its hinder end a plate of cartilage is developed in the inner alveolar wall (Pl. 9), a condition I have not observed in any other animal. Two tooth buds occupy the common alveolus, and opposite the more anterior of these Meckel's cartilage, which at first lies in a groove on the

median side of the mandible, now becomes entirely enclosed within a bony canal which, at first fenestrated, so that the cartilage is here and there visible from the inner aspect, becomes soon complete. Further forward Meckel's cartilage once more appears on its medial side, uncovered by bone, and so runs forwards to meet and fuse with its fellow along a somewhat extensive symphysis. At the extreme anterior end of this symphysis each cartilage ends freely in a small-pointed extremity. By the side of the anterior symphyseal region of the two cartilages of Meckel, there is developed in the inner alveolar wall of the inferior incisor tooth socket an accessory cartilage which is thick enough to extend to both medial and lateral surfaces of this wall. It is partly ossified, and that by invasion from the surrounding membrane bone.

The alveolus of the large inferior incisor tooth, as might be expected, is of enormous size, and although complete behind, is laterally for a considerable distance—in fact as far as the anterior extremity of the mandible—deficient.

Above and behind the incisor alveolus an oval mental foramen is seen through which the mental branch of the inferior dental nerve emerges.

A word or two may be said regarding the inferior dental nerve, and its relation to the mandible. This nerve, after becoming free of the main mandibular nerve trunk, passes downwards and outwards between the external pterygoid muscle and Meckel's cartilage, the latter to its medial side, and on reaching the cartilage the nerve to the mylo-hyoid muscle is given off which reaches the mylo-hyoid muscle between the lateral aspect of Meckel's cartilage and the angular mass of cartilage. The main trunk of the inferior dental nerve, associating itself more with the medial lower edge of the condylar cartilage, enters the mandible through the inferior dental canal formed, as already mentioned, by union of the inner alveolar wall with the root of the coronoid process; proceeding outwards, it gradually sinks in level, until it more nearly approaches the angular cartilage and Meckel's cartilage, and when the common alveolus is reached it lies under the fibrous floor of that hollow some considerable distance below the hindmost tooth bud. Later it is in fairly close relation with the medial side of the angular cartilage; later it lies between Meckel's cartilage and the outer alveolar wall, and opposite the foremost tooth bud it divides into two terminal branches, of which the uppermost, the mental branch, rises upwards and forwards and leaves the mandible through the mental foramen; the other branch runs forwards in the mandible to supply the incisor tooth.

The Vomer (Pl. 2).—This bone reaches from a point almost immediately behind the medial palatine process of the incisivum, but at a plane some-

what dorsal to it, on the medial aspect of the upper half of the medial lamella of the paraseptal cartilage; in section it is here V-shaped, and may then be said to lie below the septum nasi and the two paraseptal cartilages. The connective tissue in which it lies, and which is of the same form in coronal section, stretches upwards and laterally to reach on each side of the septum the fibrous tissue suspending the paraseptal cartilage from the septum; further back the vomer is Y-shaped in section, the stem of the Y being downwards, and lying in the narrow fissure between the bilaminar parts of the paraseptal cartilages, and the two limbs reach out and upwards almost as far as the suspensory ligament of the paraseptal cartilage on each side. Further back, where the paraseptal cartilages have lost their lateral lamella, all the limbs of the Y-shaped vomer (in section) have thickened. Still further back, where the paraseptal cartilages have been reduced to narrow rods, the vomer has again been reduced to a V-shaped form, and each limb of the V now surrounds completely the corresponding paraseptal cartilage; and it is interesting to note that the fusion of the two limbs at the apex of the V is very imperfect, only here and there, in fact, hinting at a possible ontogenetic double origin of the vomer in Microtus. When the paraseptal cartilages have been traced back to their fusion with the lamina transversalis posterior, the vomer is still continued back, but now in two separate halves along the medial edge of the corresponding lamina transversalis posterior, and the cartilage here is much altered in character, presenting the appearances associated with commencing ossification in cartilage. Each half comes to an end shortly before the cupula posterior is reached, and here each half is separated by an appreciable interval from the cartilage of the lamina transversalis posterior. In the model the anterior V- and Y-shaped parts of the vomer, being so closely wedged in between the paraseptal cartilages, could not be shown.

Mixed Bones (Entochondral and Substitution Bones).

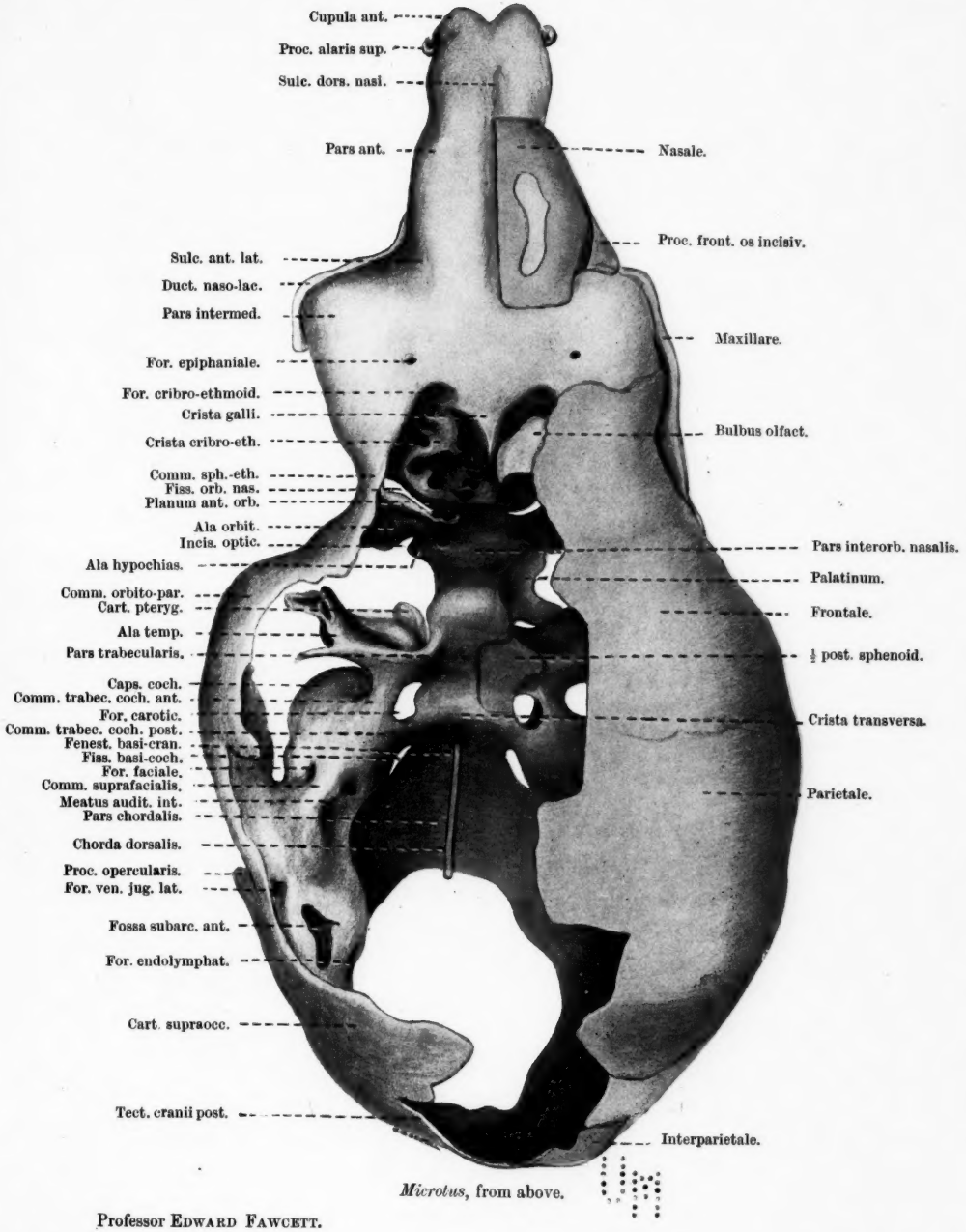
Os sphenoideum.—This is only ossified so far as the ala temporalis and post-sphenoid are concerned. The ala temporalis is only slightly invaded by perichondrial ossification along its anterior margin and along its lateral edge. This ossification is in continuity with the alisphenoid membranous ossification. At its root part, where its median ventral process (see description of ala temporalis) is found, perichondrial ossification large in amount connects it at once with the os pterygoideum and with the ossifying post-sphenoid. The os pterygoideum is therefore at an early period fused with the post-sphenoidal elements. The post-sphenoid is chiefly ossified from the investing perichondrium of the pars trabecularis. On each side of the remnant of the cranio-pharyngeal canal it is easy to see that the

cartilage is in process of absorption, and it is doubtful if the cartilage here forms anything more than a framework on which perichondrial bone is deposited. As this region is followed backwards under the lobes of the pituitary body, the cartilage of the pars trabecularis is complete, and ossification of its perichondrial investment is only apparent on its upper and lateral aspects; and by the time that the basi-cranial canal through which the notochord dips down to the region of the pharynx is reached—in other words, when the hindmost limit of the pars trabecularis is reached—the post-sphenoidal ossification ceases. The post-sphenoid, then, is essentially an ossification in connection with the pars trabecularis. I do not know if it arises by two centres corresponding with the two trabeculæ, as I long ago confirmed in man, and which, as a matter of fact, was well known; but it is possible that it may be so. At all events, double ossification of the post-sphenoid can be satisfactorily explained on the ground of its trabecular origin. No trace of pre-sphenoidal nor of orbito-sphenoidal ossification existed at this stage, nor have I any information regarding what happens in Microtus regarding these parts.

Os occipitale.—The basi-occipital and the exoccipital and the supra-occipital are in process of ossification. The basi-occipital ossification stretches from the anterior margin of the foramen magnum almost as far as the basi-cranial canal. It is to a large extent perichondrial, but does not reach out to the lateral limit of the chordal plate. The chorda dorsalis lies immediately under the perichondrial bone of the dorsal surface of the chordal plate in its whole length. This basi-occipital ossification is narrow behind at its commencement, but widens much as it is traced forwards. The exoccipital centres are primarily perichondrial, and envelop those cartilages above, in front and below but not behind, immediately lateral to the hypoglossal canals. Ossification does not reach out as far as the paracondyloid process; not further out, in fact, than the lateral margin of the upper ganglion of the vagus nerve. Behind the hypoglossal canals it invades slightly the condyle, and beyond the posterior limit of the condyle perichondrial as well as entochondral ossification is continued up along the side of the foramen magnum; later it is entirely perichondrial. This ceases opposite the level of fusion between the posterior pole of the auditory capsule and the exoccipital cartilage.

The supra-occipital is in process of ossification mainly perichondrial, but owing to the plane of section being coronal it is impossible to determine satisfactorily its limits.

In conclusion, it may be stated that the main comparative statements made here concerning the very young stages are based on personal



Microtus, from above.

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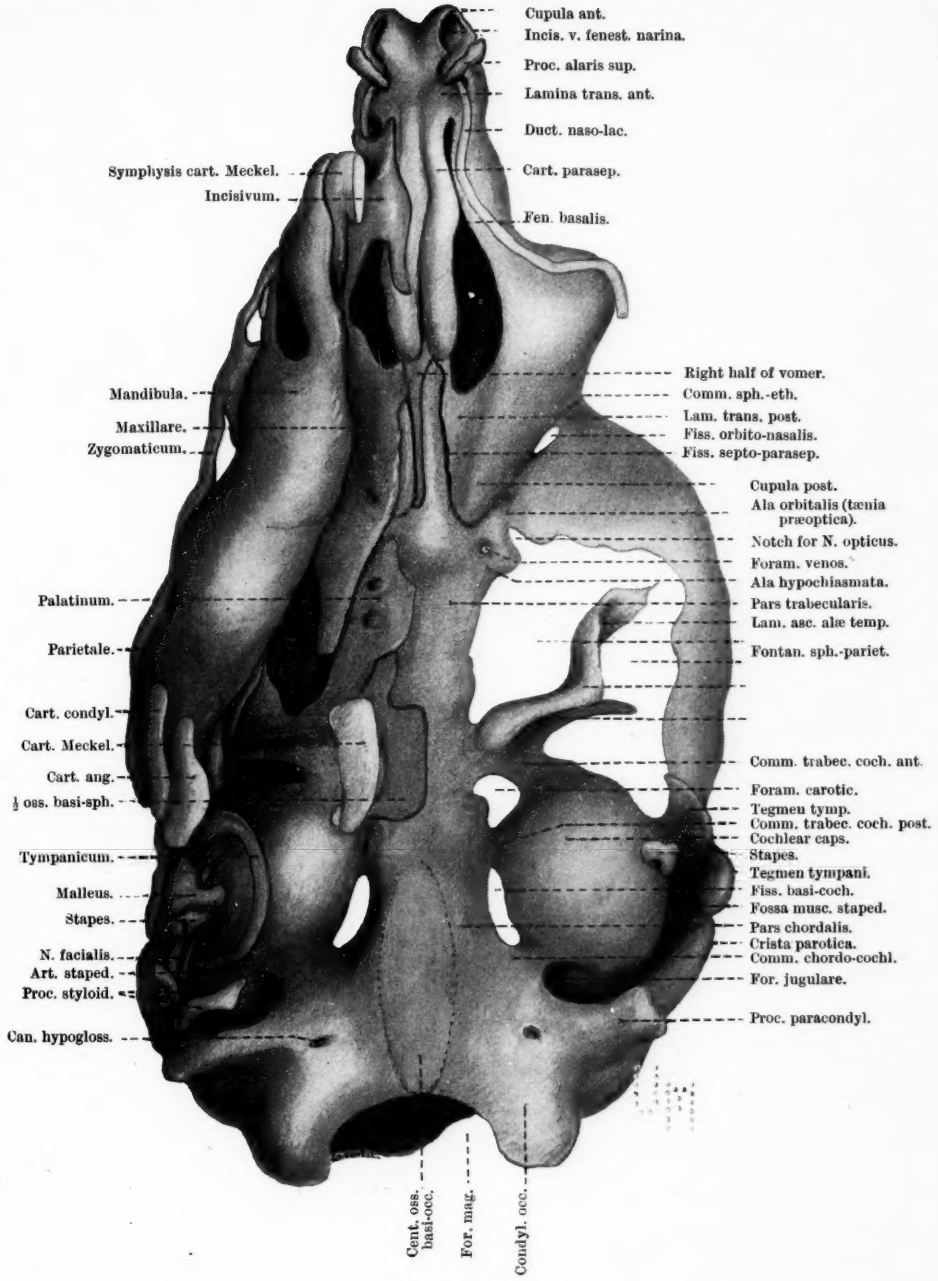

Microtus, from below.

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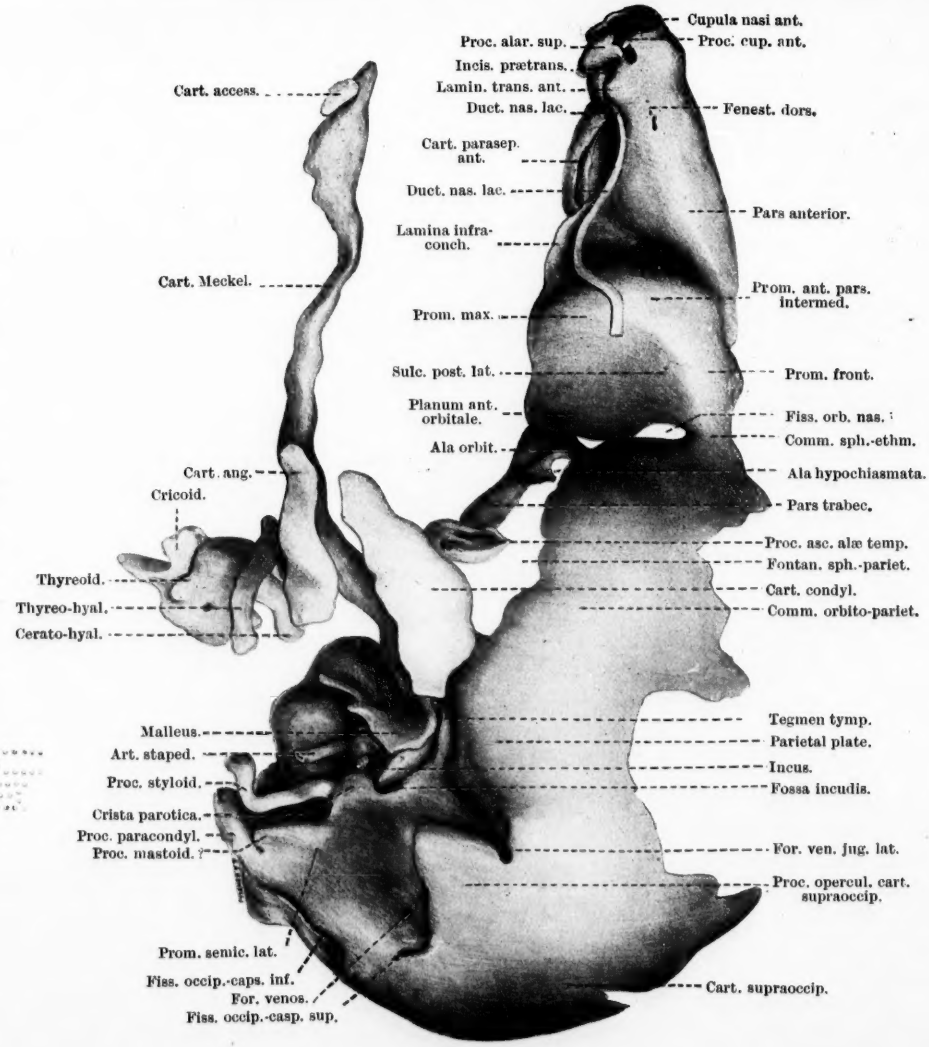
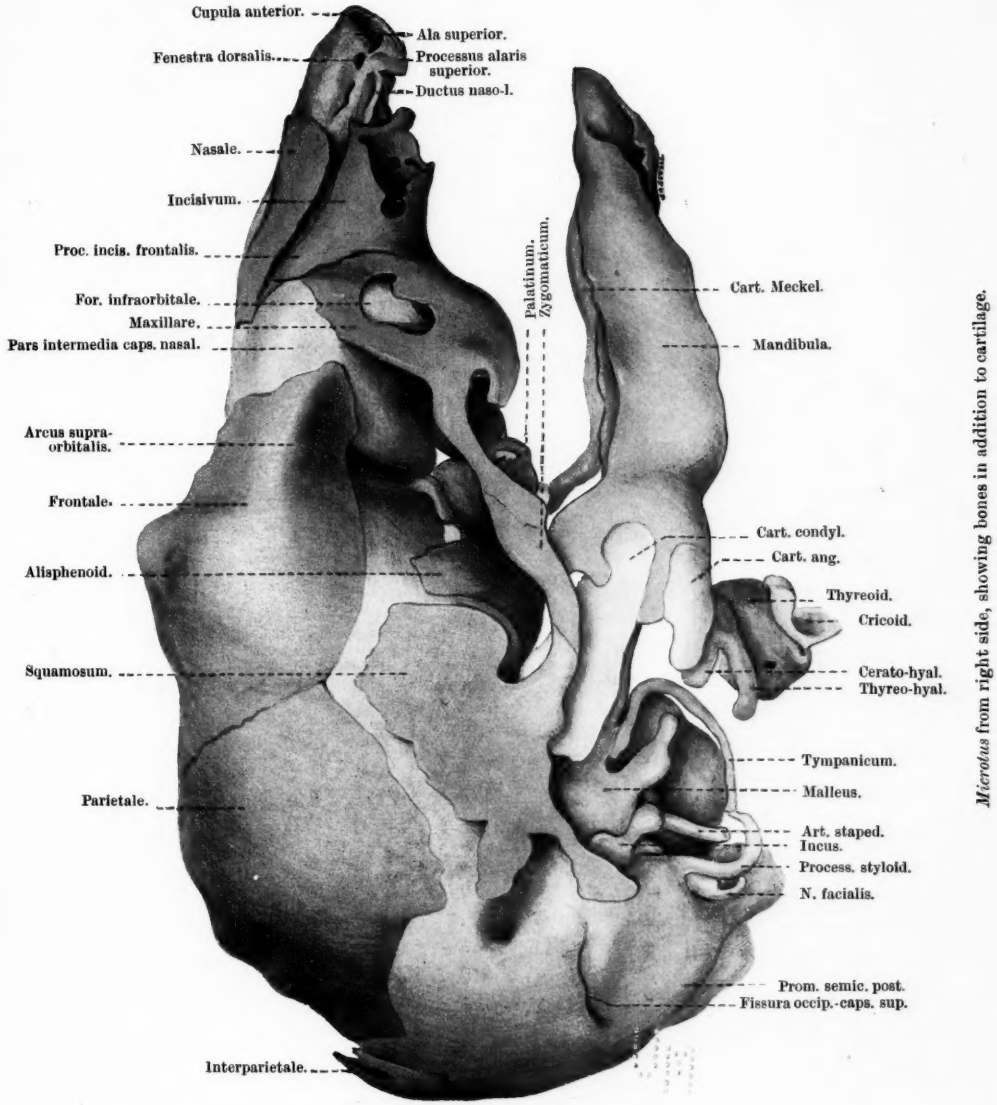
Cupula nasi ant.



Microlus, from the left side. The bones have been removed.

Professor Edward Fawcett.

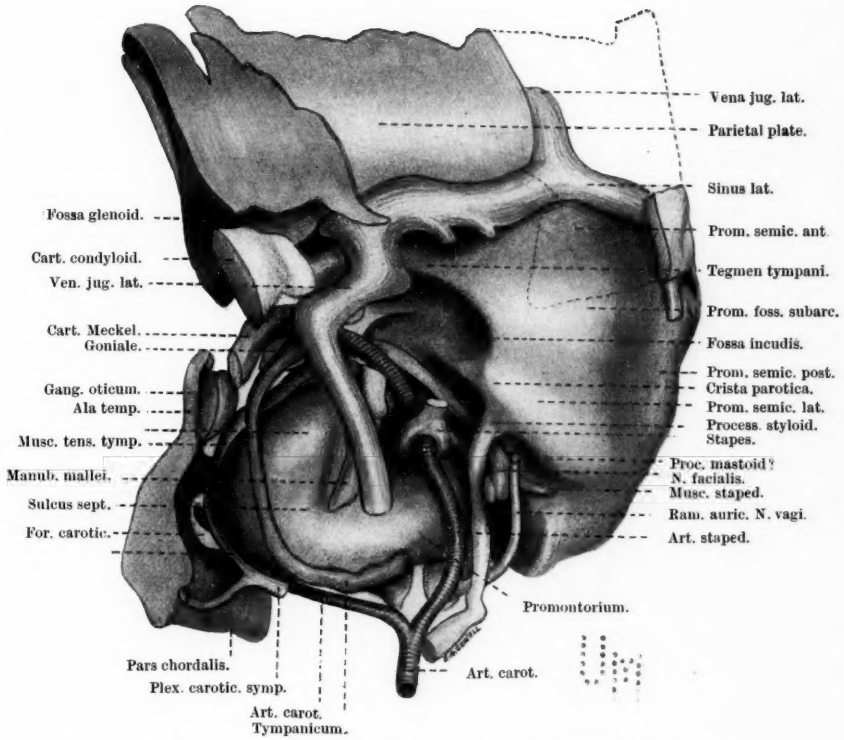


Microtus from right side, showing bones in addition to cartilage.

Professor EDWARD FAWCETT.

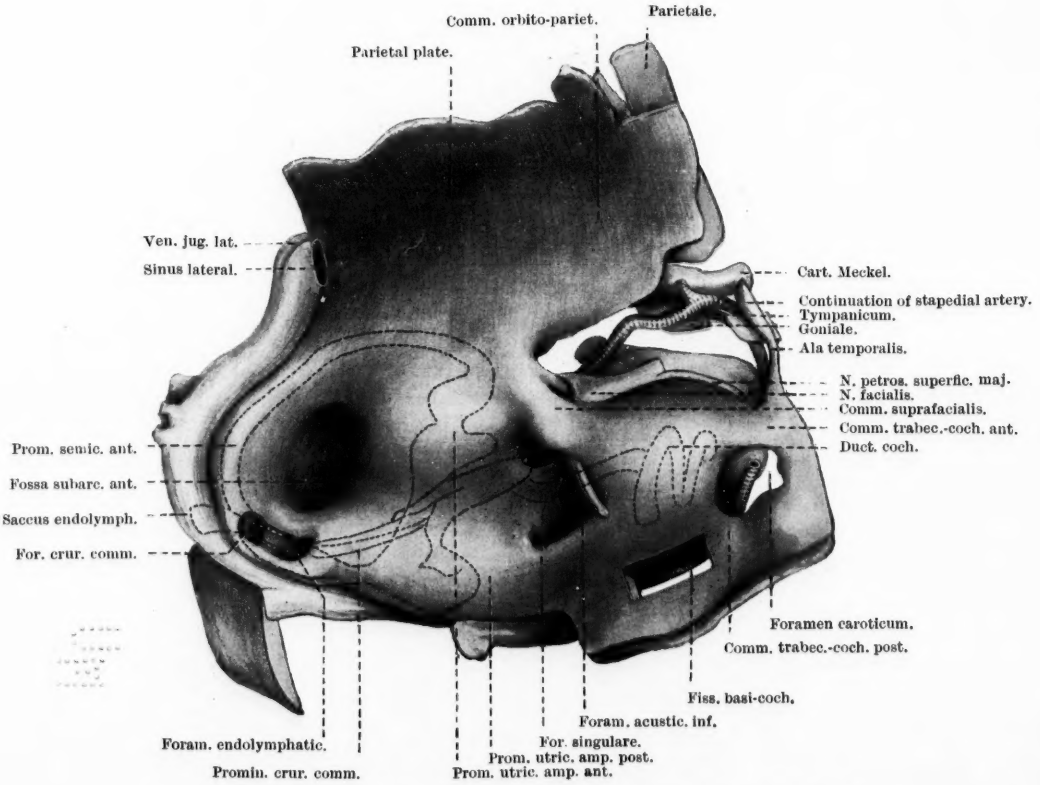
Microtus. The right auditory capsule and environs from medial aspect.

Professor EDWARD FAWCETT.

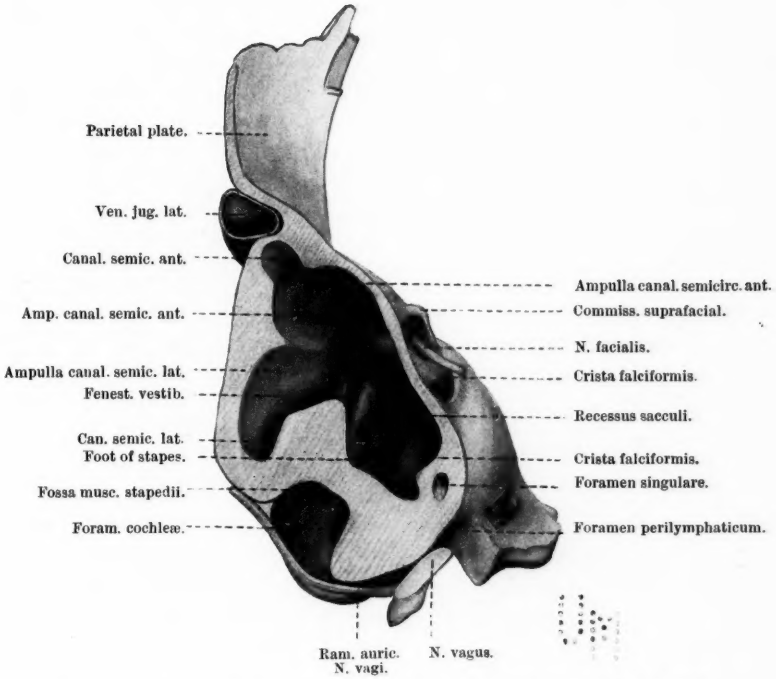


Microtus. The left auditory capsule seen from the lateral aspect, with its environs. The area enclosed by an interrupted line is the supraoccipital cartilage, with its opercular process.

Professor EDWARD FAWCETT.

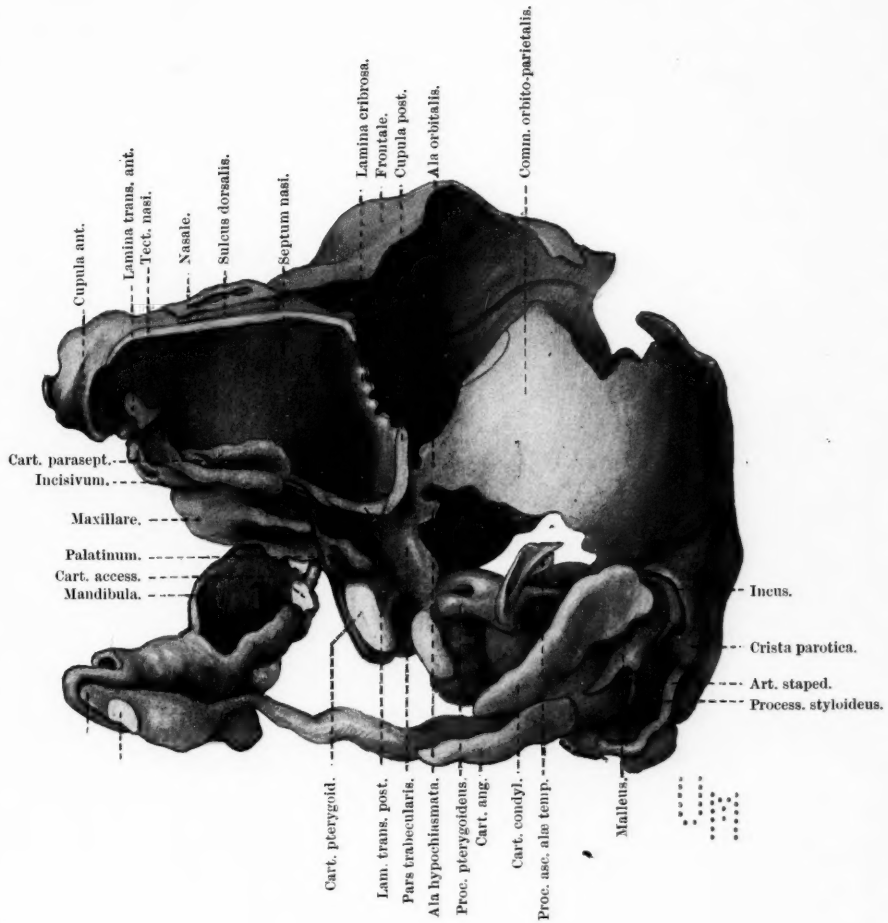


Microtus. Medial aspect of left auditory capsule, and the structures in relation with it. The membranous labyrinth is shown by interrupted lines.



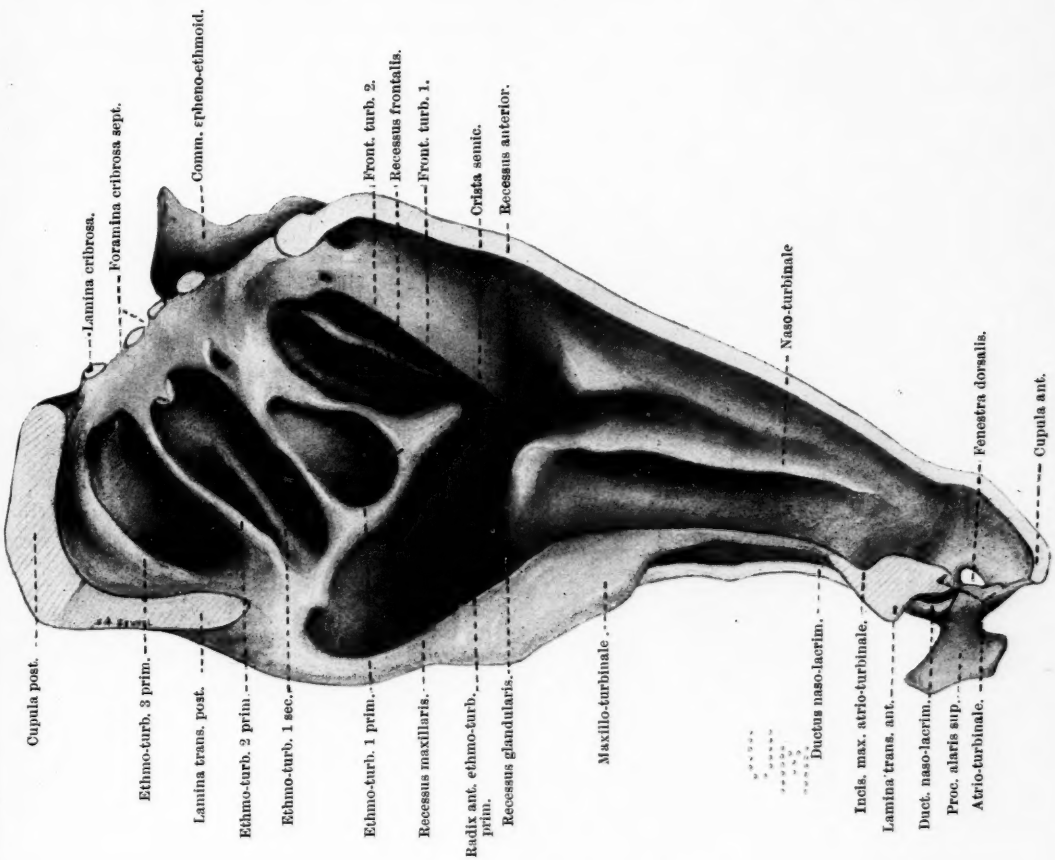
Microtus. Anterior half of coronal section of auditory capsule, viewed from behind.

Professor EDWARD FAWCETT.



Microtus. Left half of nasal wall removed, to show especially the septum nasi and appended structures.

Professor EDWARD FAWCETT.



Microtus. Medial aspect of left lateral nasal wall.

Professor EDWARD FAWCETT.

investigations of those stages on specimens stained with thionin, as recommended first by Kallius (*Anat. Hefte*, vol. xxx., 1905, p. 9). It is by far the most delicate stain known to me for cartilage; in fact, tissue which would certainly be pronounced procartilage by hæmatoxylin stain stands out clearly as cartilage when stained with thionin. The tissue must be quite fresh and be well fixed. The stain is as delicate for cartilage as Mallory's stain for bone. This communication may be regarded as introductory to many others, hence but scant reference is made to literature, but it is my duty to refer here to the kindness with which my friends Professors J. P. Hill, F. Wood Jones, Arthur Robinson, and D'Arcy Thompson have placed material at my disposal; also to the invaluable help given me by my students, Misses Casson, Neville, Brown, Llewellyn, Richmond, and Messrs Tilsley, Datta, and White, in cutting out wax plates, etc. The main illustrations have been done by Mr S. A. Sewell, whilst fig. 3 I owe to my daughter Dorothy.

The expenses of this research were to a large extent defrayed by the University of Bristol Colston Society's Research Grant.

THE ACTION OF THE BICEPS FLEXOR CRURIS.

By Professor A. M. Paterson, *Liverpool.*

It is familiar to all anatomists that the great sciatic trunk is composed of three separate nerves—the peroneal, tibial, and nerve to the hamstrings, —enclosed in a sheath in that order from without inwards. The nerve to the hamstring muscles sends its branches to the muscles supplied in one, or more often two, bundles. It supplies the long head of the biceps: the short (femoral) head being supplied by the peroneal nerve.

It has further been shown that the short head of the biceps is closely related morphologically to the gluteus maximus. In Ruminants they form one muscle, the long vastus. In man they are occasionally supplied by a common nerve (the inferior gluteal) carrying the fibres (L. 5, S. 1, 2) for the supply of the short head of the biceps—as well as the gluteus maximus.

In view of these facts it is interesting to observe, as I have had the opportunity of doing recently, the effect of division of the peroneal nerve in gunshot wounds of the buttock. Cases are occasionally found in which only the outer part of the great sciatic trunk is divided, resulting in paralysis and anæsthesia in the area of distribution of the peroneal nerve alone. In such cases there is paralysis of the short head of the biceps, but the hamstring muscles, including the long head of the biceps, remain active.

The result of the elimination of the short head of the muscle is well seen when the patient lies on his face and flexes the knee. The long head of the biceps becomes taut in the early part of the movement, but when the limb is semi-flexed its function ceases and the tendon becomes flaccid—the reason being the absence of the aid derived in normal conditions from the contraction of the short head, which keeps taut the tendon of the muscle.

Furthermore, there is a hollow produced in front of the tendon of the long head during contraction, instead of a swelling due in the normal muscle to the contraction of the short head.

The movement of external rotation of the knee seems to be due to the agency of the long head of the muscle.

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PATERSON, A. M., "Sacral Plexus in Man," *Journal of Anatomy*, vol. xxi. p. 407.

PATERSON, A. M., "Limb Plexuses of Mammals," *Journal of Anatomy*, vol. xxi. p. 611.

PATERSON, A. M., "Origin and Distribution of Nerves of Lower Limb," *Journal of Anatomy*, vol. xxviii. pp. 84 and 169.

CHAUVEAU, *Comparative Anatomy of the Domesticated Animals.*

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THE FORM OF THE URINARY BLADDER.

By A. R. Thompson, Ch.M., F.R.C.S., *Surgeon in Charge of the Genito-Urinary Department, Guy's Hospital.*

During the past six years, as chief of the Genito-Urinary Department of Guy's Hospital, I have had reason to alter my conception of the form of the urinary bladder, and to consider that the descriptions usually offered in the text-books which deal with the subject are by no means adequate.

The following difficulties have occurred, in my own knowledge and experience, which are not adequately explained by the conception of a regular and symmetrical bladder occurring in the living subject.

The form of the bladder, in the living subject, is revealed by the cystoscope, which is a scientific instrument of precision. These are the difficulties:—

1. The asymmetry of the ureteric ridges, and the position of the ureteric orifices.
2. The difficulty of seeing, in some cases, the ureteric orifices, with the aid of the cystoscope.
3. The difficulty, in some cases, of completely draining a bladder, for a short or a long time, by means of a catheter.
4. A symmetrical stone, regular in outline, may be placed in an asymmetrical position as revealed by the X-rays, and the bladder sound.
5. The irregular passage of urine before, during, and after defæcation.
6. The apparent unwillingness of even expert surgeons to perform the operation of lithotrity, an operation which should not be attended with much risk, were the bladder symmetrical in form and position.

Before the war an investigation was begun by me into the shape of the bladder, with a view to demonstrating points in cystoscopy. The results of this investigation cleared up, in a satisfactory way, many of the difficulties, if not all, which have been enumerated. I thought it worth while, therefore, to bring these results before you at this meeting of the Anatomical Society (Friday, 1st December 1916).

For the results of this investigation I am indebted to the old-fashioned

plan of the injection of plaster of Paris into the empty viscus in known amounts.

The bladders of subjects not long dead, and even in some cases with rigor mortis present, and in no case dead longer than twenty-four hours, were injected with plaster of Paris in a liquid state. Some of my latest specimens, *e.g.* Nos. 13 and 16, were injected within two hours of death.

The results of these investigations have convinced me that the form of the bladder is very variable. The shape of the casts resulting from the setting of the plaster fully explains, and agrees with, the shape of the living bladder revealed by the cystoscope.

In my collection of casts of the bladder there are twenty specimens. Only a few of the casts are complete, as it is very difficult to drain a bladder completely with a catheter, and a certain amount of fluid is left in the bladder unavoidably. This fluid does not mix with the injected plaster, and rises to the top of the bladder, and thus a flat surface of plaster is left. During catheterisation air also may enter the bladder.

This flat surface, however, helps us to place the cast in its true position. The bodies lay horizontally upon a metal table, and the specific gravity of the liquid plaster as shown by Hare's apparatus is 1·38.

It is possible that the flat surface is anatomical, and not accidental *e.g.* in No. 16.

The casts are numbered from 1 to 20, and have been grouped together according to weight.

Group I.—$2\frac{1}{2}$–$4\frac{1}{4}$ ounces. Nos. 2, 3, 4, 5, 6.
Group II.—$5\frac{1}{2}$–$8\frac{1}{4}$ ounces. Nos. 7, 8, 9, 10, 11.
Group III.—11 ounces. Nos. 12, 13.
Group IV.—$13\frac{1}{4}$–15 ounces. Nos. 14, 15, 16.
Group V.—Infants and children. Nos. 1, 18, 19, 20.

Description of Individual Casts. Under Groups, Relative to Erect Attitude.

Group I.—$2\frac{1}{2}$–$4\frac{1}{4}$ ounces.

No. 2.—Age not recorded—weight $2\frac{1}{2}$ ounces. The specimen shows considerable asymmetry, extending forwards and to the left, and bulging backwards and to the right. The trigonal region, or base, is egg-shaped, being broader on the left side. There is a continuous ureteric ridge, not so well marked in the centre as laterally, near the ureteric orifices. The bladder is much broader at the base than at the fundus, and I imagine, from the usual shape of bladder retractors, that this specimen affords the average surgical conception of the form of the bladder.

No. 3.—Male, aged 21, displacing $3\frac{1}{4}$ ounces of water; shows, as rather a marked feature, the relative flattening and breadth of certain bladders.

No. 4.—Female, aged 61, displacing $3\frac{1}{2}$ ounces of water; shows much more of the bladder situated upon the left side of the middle line. The flat surface is clearly accidental. The specimen shows a sacculus, situated on the left side, and in the line of the left ureteric ridge.

No. 5.—Young male subject, displacing 4 ounces of water. It is practi-

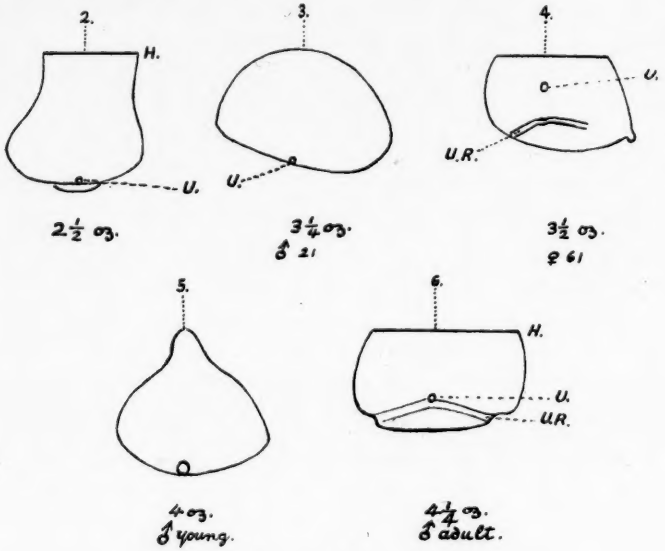


FIG. 1.—Group I. (Scale $\frac{1}{3}$ nat. size.)

General references to diagrams.

H., horizon; U., urethral orifice; U.R., ureteric ridges; U.O., ureteric orifices; P.I., prostatic impression.

cally symmetrical. There is a very large entrance to the urethra. This last feature should be associated with the marked symptoms of vesical calculus in young people, and the relatively frequent occurrence of passage of calculi from the bladder into the urethra in young as compared with old people.

No. 6.—Age unknown, probably male, as there is a prostatic impression; shows relative flattening and broadening of the bladder. There is much more of the bladder on the left than the right side. The ureteric ridges meet at the neck of the urethra, without the intervention of a uvula.

Such cases are not uncommonly met with during a cystoscopic examination, and present difficulties in the passage of a ureteric catheter.

Apart from its asymmetry, this specimen follows closely Professor Dixon's masterly description of the bladder.

General Considerations of Group I.

The specimens lose some of their value owing to the flat surface mentioned in the introductory portion of this paper. Complete symmetry does not occur in any one of them. A greater part of the bladder is situated on the left side in three cases and on the right side in one case. The ureteric ridges are continuous, but show, in No. 2, a tendency to what I believe may be regarded as the infantile type (*vide infra*). In one case, No. 6, there is, strictly speaking, no area between the urethra and the ureteric ridges.

GROUP II.—$5\frac{1}{2}$–$8\frac{1}{4}$ ounces.

No. 7.—Age and sex not recorded, displacing 6 ounces of water.

This is a cubical-shaped bladder. The base is well marked, and shows, laterally, two symmetrical, well-marked depressions directed backwards and downwards, lying one on each side of the lower portion of the bowel. The ureteric ridges are of the infantile type, and the trigone is large. This is a symmetrical bladder.

No. 11.—Age and sex not recorded; shows an oblong bladder, displacing $8\frac{1}{4}$ ounces of water. Its longest axis is transverse. The lateral parts of the base are bulging slightly downwards. The base shows a strongly marked uvula. The ureteric ridges are not quite continuous, being separated by a slight groove. There is slight asymmetry of the bladder, more being on the right side of the middle line than on the left. The ureteric ridges are equal in length, but, owing to the asymmetry of the whole organ, the right does not extend relatively so far outwards as the left.

No. 8.—Male, aged 60, displacing 7 ounces of water; is a poor specimen, but is an accurate representation of the shape of the particular bladder. It shows the upper part of the bladder situated asymmetrically and to the left of the middle line. Its base is nearly symmetrical; the ureteric ridges are practically continuous with each other and a well-marked uvula. The base gives no indication of the asymmetry of this bladder. Doubtless if this bladder had become overfilled it would have passed upwards, and to the left of the middle line, and not to the right. Speaking from memory, I should say that bladders when overfilled in many cases do not keep accurately to the mid-line, but pass upwards to the right.

No. 9.—Male, aged 48, displacing $5\frac{1}{2}$ ounces of water; shows a typical bladder, with slight obliquity upwards and to the left. There is a small

prostatic depression. The ureteric ridges are well marked and continuous. The trigone looks forwards as well as downwards.

No. 10.—A female, aged 52, displacing $5\frac{1}{2}$ ounces of fluid; not quite complete at the fundus; the horizontal surface thus formed, and the

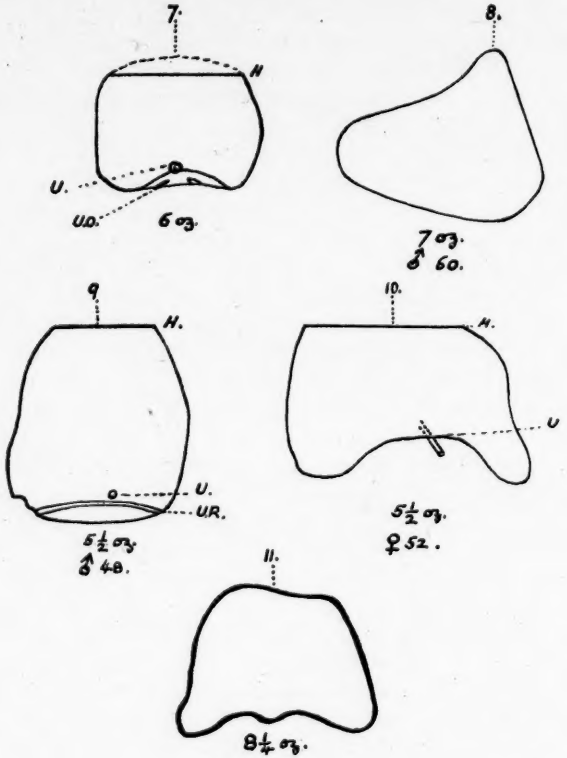


FIG. 2.—Group II.

direction of the catheter, help us to place the bladder cast in its correct position. In this specimen the adaptation of the shape of the bladder to the other pelvic viscera is particularly well marked. The lateral expansions outwards, downwards, and backwards are also particularly well marked. There is much more of the bladder situated on the right than the left side. The long axis of the bladder is directed backwards and to the right. There are signs of a ureteric ridge, and perhaps the ureteric orifice on the left

side in actually looking outwards in what may be called the pararectal fossa of the bladder. I have no hesitation in regarding this cast as a true representation of the form of this subject's bladder. I have come across such cases clinically. They are difficult cases to cystoscope, and in whom to pass ureteric catheters. One could understand such a bladder causing great trouble to the obstetrician, gynæcologist, or surgeon.

General Considerations of Group II.

The bladders forming this group may be considered as holding the quantity of urine which usually produces the desire to micturate. It is therefore an important group. The direction in which the trigone looks is

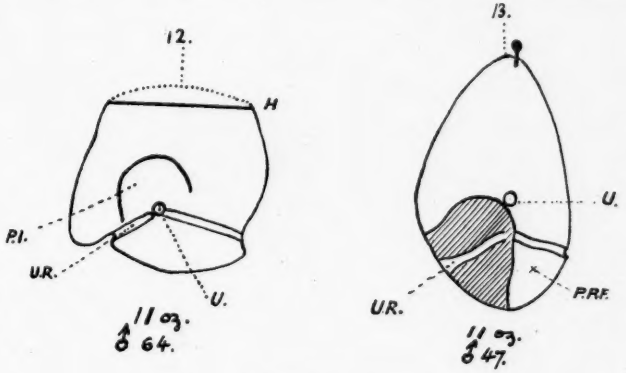


FIG. 3.—Group III.

very variable, but it will be more convenient to consider this later. Only one, viz. No. 9, in any way corresponds to the shape usually described. Two of the bladders are cubical or oblong in general shape. One is quite irregular, as regards its fundus (No. 8), and one (No. 10) shows well-marked pararectal fossæ, which are also present, but much less well developed in Nos. 7 and 11.

GROUP III.—11 ounces.

This group consists of two specimens, and may be considered as holding a little more than the usual quantity of urine which necessitates micturition in the normal person. They are neither of them typical in shape, and both differ from each other very markedly. They both displace similar quantities of water, viz. 11 ounces.

No. 12.—Male, aged 64. This is roughly cubicle in shape, and asymmetrical, much more of the bladder being on the left side than the right.

There is a well-marked prostatic impression. The ureteric ridges are asymmetrical as regards size and position, the right being much higher and prolonged on to the posterior aspect of the bladder. There is no trigone, the ureteric ridges converging upon and meeting with each other at the urethral orifice. This would, I think, be a difficult bladder for one to cystoscope accurately.

No. 13.—Male, aged 47, displacing 11 ounces of fluid; has a hat-pin which was inserted into it vertically just above the pubes in the mid-line when the body was horizontal. This cast was made, the body being under four hours dead. The fundus is slightly to the right of the middle line. The outstanding feature of this specimen is the very large fossa on

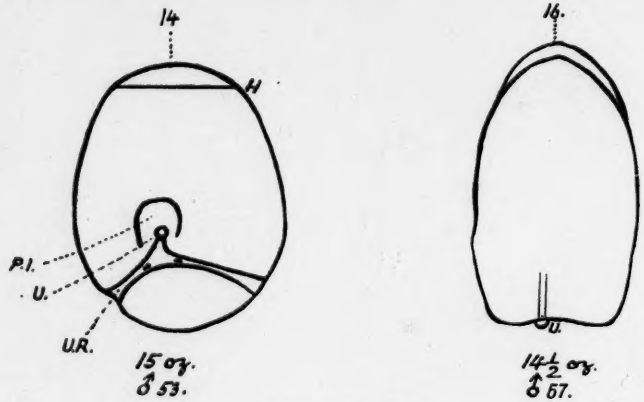


Fig. 4.—Group IV.

the left side directed backwards and slightly downwards. In spite of this large pararectal fossa, probably more of the bladder lies on the right side than the left. The ureteric ridges are symmetrical, and both are prolonged on to the lateral aspect of the bladder. The ridges are continuous with each other, but not very well marked. Neither of the bladders in this group may be considered typical in shape. No. 12, however, reproduces the cubical shape, previous specimens of this shape having been demonstrated.

Group IV.—13¼–15 ounces.

No. 14.—Male, aged 53, displacing 15 ounces of fluid; tends to reproduce the cubical shape described before. It is asymmetrical, more of the bladder being situated upon the left side. It shows a well-marked colic depression on its upper and back aspect. The ureteric ridges are well marked, and

converge upon a very distinct uvula, half an inch long, proceeding forwards to the urethra. There is a well-marked prostatic impression.

No. 15.—Male, aged 44, displacing 13¼ ounces; except that it shows a well-marked pararectal fossa, is a cast of a cast, and therefore in itself calls for no special description. The reason of my thus neglecting any special description of it is explained by the following specimen, of which it forms a part.

No. 17 does not fall into any group, as it is a composite production. 150 c.cm. of liquid plaster were injected into the bladder and allowed to set. 150 c.cm. of blue plaster were then injected through the right ureter. This was allowed to set, and then 150 c.cm. of red plaster were injected through

Nos. 15 and 17.

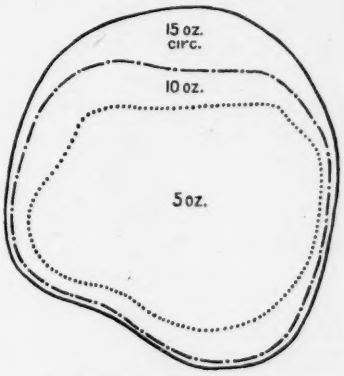


Fig. 5.—Bladder injected as described in the text.

the left ureter. Unfortunately the external casing was very thin in parts, and during the disorganisation of my department, consequent upon the beginning of the war, was smashed. The fragments were, however, preserved, and I was able to piece them together roughly and make the cast No. 15.

A coronal section, probably directed downwards and slightly backwards, was made of the two inner casts, and the specimen coloured after being fixed in a plaster mount (fig. 5). It is an attempt to show changes which take place in the bladder as it is filled. The inside yellow cast represents a bladder holding about 5 ounces of fluid. A left pararectal fossa is obvious. When another 5 ounces is injected it will be observed, by reference to the blue cast, that the bladder fills up chiefly at opposite poles, viz. right upper pole and left lower pole. The latter is responsible for an

increased development of the pararectal fossa. The outer cast, of which No. 15 forms an inadequate representation, showed with another 5 ounces of plaster injected very little increase of this pararectal fossa. This pararectal fossa is therefore not to be associated with the overfilling of a bladder.

No. 16.—Male, aged 57, injected within four hours of death; cast displaces 14½ ounces of water. It is of the shape usually described in text-books, although more of the bladder is on the left side. It is interesting as showing, with a few other specimens, that the typical shape of the bladder can be reproduced by these plaster casts, and that therefore the shapes other than typical which I have described cannot be disregarded. A pin driven in just above pubes in mid-line passed through the urethral orifice of the bladder.

Group V.—Young subjects.

No. 20 simply demonstrates that plaster will make a very good reproduction of the fasciculi of a small contracted bladder.

No. 1 is a cast of a bladder of a female aged four months, displacing 2 ounces of fluid. It affords a good demonstration of the very large part of the bladder contained in the abdomen in young subjects. The position of the brim of the pelvis is clearly shown. Generally speaking, the cast is symmetrical and typical, but the pelvic part shows distinct antero-posterior compression on the left side owing to the pressure of the pelvic colon.

No. 18.—Male, aged 11 months, displacing 3¾ ounces of fluid; shows the same features as No. 1, but in a more marked degree.

No. 19.—Female, aged 3 years, displacing 5 ounces of fluid; shows similar features. Pararectal fossæ, in addition, are well marked, especially on the left side.

Two of these specimens, No. 1 and No. 19, show small discontinuous crests upon which the ureteric orifices are situated, and in No. 18 the continuity of a ridge is by no means established. I am inclined to think these crests rather than ridges, continuous with each other, are more common in children than adults. The young bladder shows, therefore, ureteric crests; the adult bladder ureteric ridges continuous with each other.

Varying Direction of Base of Bladder.

Rough measurements of the angle of general direction in which the trigone looks, or failing this the base of the bladder, have been made in some of these specimens, and is found to vary according to the following diagram. The horizontal is taken with the subject in the dorsal position in order that the angles may be co-ordinated with cystoscope.

This variation of direction of the base, or trigone of the bladder, is of

great importance in cystoscopy. The best view I ever had with a cystoscope was in an elderly man, in whom I held the cystoscope nearly vertical; on the other hand, in many cases it is necessary, in order to see the trigone, to hold the cystoscope below the horizontal.

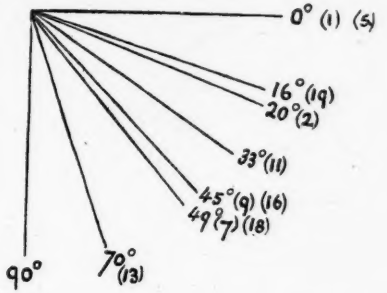


FIG. 6.—Represents the angle which the trigone, or base of bladder, makes with a known horizon.

The figures in brackets refer to individual casts.

The angle which the ureteric ridges or crests make with each other or the sagittal plane vary, but I have not had time to go into the measurements yet.

GENERAL CONSIDERATIONS RELATIVE TO THE FORM OF THE BLADDER IN THE ADULT.

Nos. 2, 3, 5, 6, 9, and 16 may be considered to belong to types usually described.

Nos. 7, 9 and 12 are more cubical in shape than types usually described.

Nos. 7, 10 (especially), 11, 13 (especially) and 15 show either unilateral or bilateral pararectal fossæ.

Nos. 3, 6, 7, and 11 are the only ones which are approximately symmetrical.

Nos. 4, 5, 6, 8, 10, 12 and 13, 15 and 16 show more of the bladder on the left side than on the right.

Nos. 9 and 11 show more of the bladder on the right side than on the left.

The following conclusions may therefore be deduced from the foregoing observations:—

1. The bladder is frequently asymmetrical in form and position.
2. The trigone may vary in superficial area, sometimes not existing at all. It may also vary in the direction in which it looks.
3. Prolongation of the bladder on one or both sides of the vagina and rectum, or rectum only, is not uncommon.

4. These departures from the type usually described offer an explanation of many of the difficulties met with in bladder surgery and treatment.

It would appear further that the same bladder, filled with different

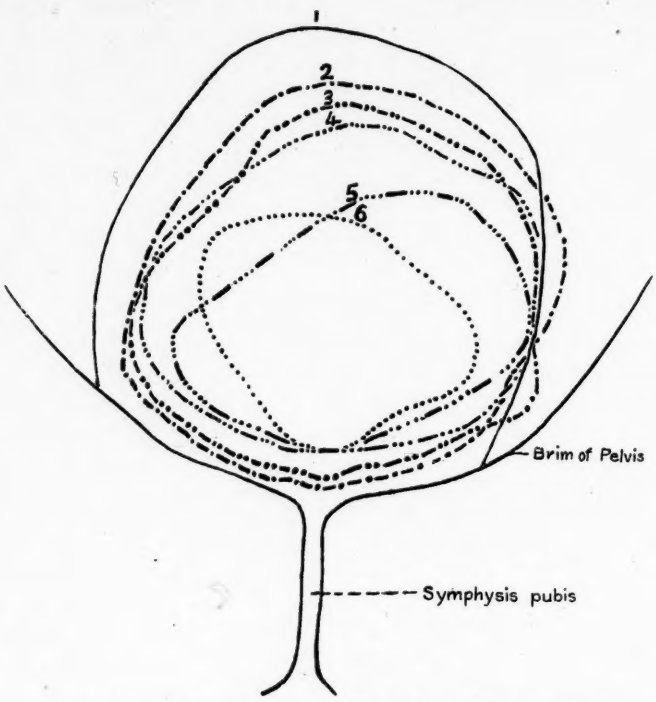


FIG. 7.—Living bladder injected with collargol from X-ray photographs, as described in text.

No. 1, represented by continuous line,				holds 2 oz. more than			
No. 2,	,,	— • — •	which	,,	,,	,,	
No. 3,	,,	— — • — • — —	,,	,,	,,	,,	
No. 4,	,,	— — — • — • — — —	,,	,,	,,	,,	
No. 5,	,,	— — — — — —	,,	,,	,,	,,	
No. 6,	,,	- - - - - - - - - - - - - -					

quantities of fluid, varies in shape, as depicted in the above diagram, constructed from X-ray photographs of a bladder filled with collargol and then photographed. Five successive photographs were then taken, with two ounces of collargol removed before each photograph. The change in form is quite apparent, especially when No. 5 is compared with No. 6.

THE SUPRACONDYLOID TUBERCLES OF THE FEMUR.

By Y. G. NADGIR, M.S., F.C.P.S., *Grant Medical College, Bombay.*

IN the October 1914 number of the *Journal of Anatomy and Physiology* Dr J. S. B. Stopford has described the supracondyloid tubercles of the femur. His observations are based on an examination of 286 adult femora, and his conclusions can briefly be stated thus:—

(1) The medial supracondyloid tubercle is a constant structure, being absent in only one out of 286 femora examined.

(2) In the series examined, it was sufficiently pronounced to make it possible to distinguish the medial aspect of the inferior extremity of the femur solely from its presence.

(3) It appeared as a nodular elevation in 80 per cent., a large projection in 8 per cent., and a slight elevation in 11·2 per cent. of the femora examined.

(4) Its position is constant, being proximal to the medial condyle and lateral to the medial epicondylar line.

(5) It is of diaphyseal origin, being present only in adult femora.

In order to verify these statements, I examined in all 177 adult femora from the anatomical collection of the Grant Medical College, and was surprised to find that the tubercle, so constant in European and ancient Egyptian femora, was absent in 130 out of the 177 bones examined. Further, in only 8 out of the 47 bones which showed the tubercle did it approach in size the average tubercle of Dr Stopford's series of bones. It was very slightly marked in 16 and fairly marked in 23. Thus it will be seen that in this series the tubercle was absent in 73·5 per cent., slightly marked in 9 per cent., fairly marked in 13 per cent., and well marked in 4·5 per cent.

The cause of this marked variation regarding the presence of the tubercle may probably be explained by the peculiar habits of the Indians. An average Indian is sitting tailorwise or squatting on the ground throughout the greater part of the day. In this position, the gastrocnemius is completely relaxed and there is no tension upon the points of its attachment. On the other hand, when a person is sitting on a chair or a stool, the gastrocnemius is not completely relaxed; and if in addition the heel be raised there is a decided tension upon the points of its attachment. Now, as in the average position the medial part of the muscle is under greater tension than the lateral part, it is probable that this continuous tension may be one of the factors in the development of the tubercle.

In regard to the situation of the tubercle and its absence in the young femora, I entirely agree with the observations of Dr Stopford.

A NOTE ON SOME CHARTS REPRESENTING THE RELATIONS OF CRANIAL LENGTH AND BREADTH.

By W. L. H. Duckworth, M.A., M.D., Sc.D., *University Lecturer in Physical Anthropology, Cambridge.* (With Charts I. to XIX.)

In reporting upon measurements of dissecting-room subjects at the Cambridge Anatomy School (*cf.* this Journal, vol. li., January 1917, pp. 167 *et seq.*), I had occasion to discuss the grouping of the crania according to their length. The tabulation (Table IX. of the communication mentioned above) forms the starting-point of the present note. For this reason I reproduce the table here (as Table I., *infra*), with the addition of letters to distinguish the various subdivisions (called groups) of the series, and of columns in which the rate of increase is indicated by figures.

Table I.

Grouping by length.	Group letter.	No. in group.	Mean length of group.	Increase in length on mean of preceding group.	Mean breadth of group.	Increase in breadth on mean of preceding group.	Mean breadth index of group.
Crania up to, but not exceeding 175 mm.	A	7	173·0	0	133·0	0	77·4
Crania from 175·1 to 180 mm.	B	15	178·0	5	138·6	5·3	77·6
,, ,, 180·1 to 185 ,,	C	23	183·0	5	141·7	3·1	77·3
,, ,, 185·1 to 190 ,,	D	42	187 8	4·8	141·8	·1	75·3
,, ,, 190·1 to 195 ,,	E	24	192·7	4·9	142·8	1·0	74·1
,, ,, 195·1 to 200 ,,	F	6	197·8	5·1	145·6	2·8	73·8
,, ,, 200·1 to 205 ,,	G	1	202·0	4·2	151·0	5·4	74·8
Totals . .	...	118	..	29·0	...	17·7	...

The table (I.) shows that the increase in length amounting in all to 29 units is effected in a fairly regular sequence, the successive increments being nearly of equal value and approaching the arbitrary value (5) by which the groups (A, B, C, etc.) are separated. Reference to the corresponding data for cranial breadth shows successive additions, it is true, but the irregularity of the sequence (5·3, 3·1, ·1 as in Table I.) is striking, and the total increase amounts to 17·7 units (as against 29 for length).

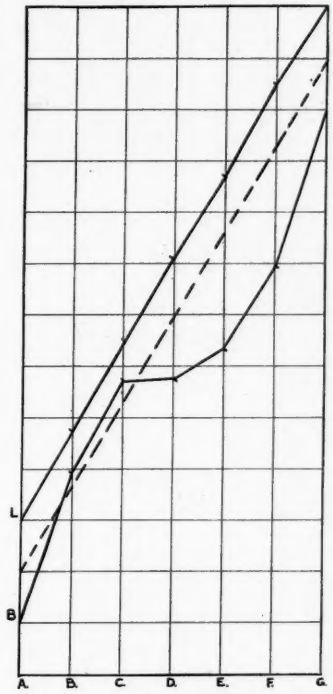


CHART I.

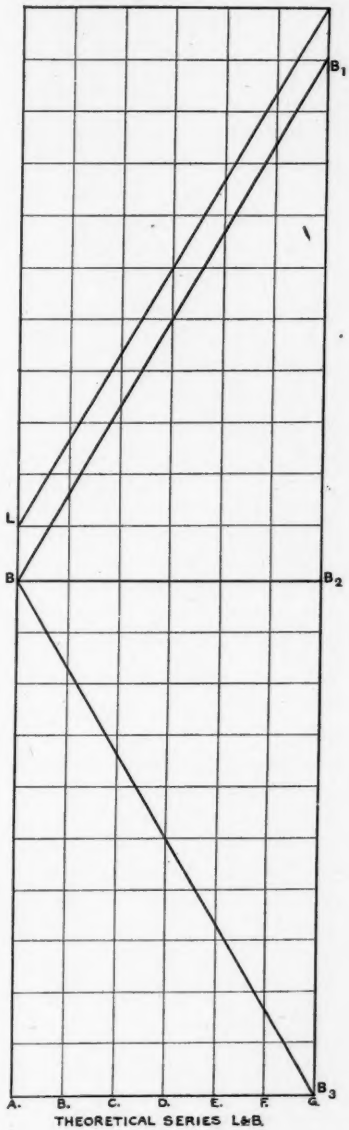


CHART II.

The present note gives the results of an inquiry as to whether the so-called sequences and the contrast between them are distinctive of the particular "material" (*i.e.* the series of dissecting-room crania, called Series "DR") under review. Diagrams for illustrating the comparison of one series with another were prepared as follows.

Each successive increment whether of length or of breadth is first expressed as a percentage of the total range of variation of the character in question. Thus in Series "DR" (Table I.) the length increases from 173 mm. to 202 = 29 units. The successive increments (5, 5, 4·8, etc.) are expressed in terms of 29 taken as = 100. A chart is prepared by subdividing a base-line into equal parts, the abscissæ corresponding in number to that of the subdivisions or groups (A, B, C, etc. . .) into which the series has been thrown. Ordinates erected in sequence represent the sum of successive increments of the particular dimension studied, and they vary in vertical extent from 0 to 100 units. The path followed by the dimension in its course from group to group through the series is traced by joining the ends of the successive ordinates. When this has been done in the cases both of length and of breadth, lines of length-increase and of breadth-increase are available for comparison (Chart I., L and B). For each dimension a separate base-line has been employed in Chart I., but this is a matter of convenience only.

But before proceeding with Chart I., I would direct attention to Chart II. This is theoretical, for it refers to no particular series though it represents lines of variation of two dimensions such as cranial length and breadth. Moreover, it is assumed that a series has been subdivided into groups according to the increasing value of one of the dimensions, *e.g.* the length. The increments in length being equal from stage to stage throughout, the length-line (L, Chart II.) ascends regularly from 0 to 100, its maximum value. I think three possible courses are open to the second line (B) representing the second dimension, and these possibilities may be thus described:—

1. The breadth may increase with the increase of length. The increase may either be regular, *i.e.* uniform in amount, or irregular. So long as the second dimension increases with consistent regularity, its "indicator" or line will pass in the same direction as the length-line. And if regularity is maintained throughout the series, the second line will run parallel to that first drawn (*cf.* Chart II., L and BB_1), correlation will be perfect, and its coefficient = 1.

2. A second possibility is that the breadth remains unchanged throughout the series. The breadth-line will then coincide with the base-line (Chart II., BB_2), no correlation will exist, and the coefficient will = 0.

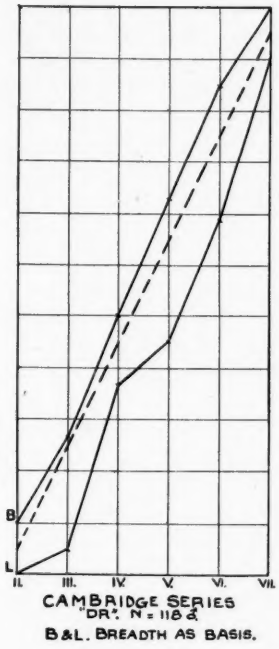


CHART III.

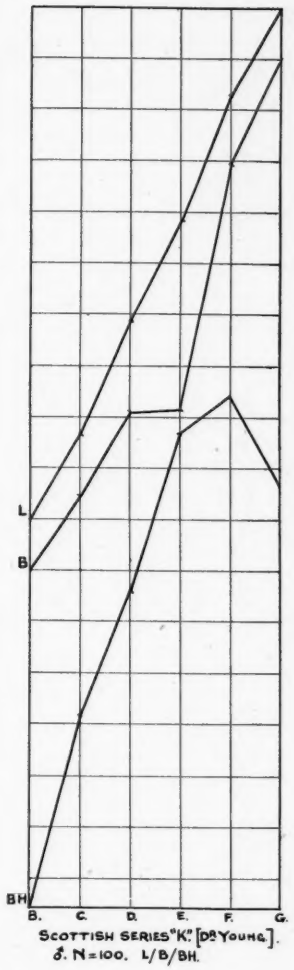


CHART IV.

3. Lastly, the breadth may decrease while the length increases. Then the breadth-line will diverge from the length-line (Chart II., BB_3), correlation will be of the negative order, and if the decrease be consistently regular from end to end through the series, correlation will again be complete though the coefficient will $= -1$.

Chart II. shows one method of representing these possibilities. Combinations of the three modes must be almost infinite in number, and indeed the later charts show some of the variants. I wish to emphasise the point that I make no attempt to provide a measure of correlation, my prime object being to exhibit the actual fluctuations of cranial dimensions within a series, and to compare the behaviour of cranial breadth in relation to length in the several series actually studied. But I have mentioned the coefficient of correlation because I suppose it to be of the nature of a "mean" or average struck between a number of quantities of very different value. And though the charts do not provide a measure of correlation, yet I think they do indicate the range of variation summarised in the coefficient.

Returning to Chart I., and having regard to the breadth-line (B), the outstanding feature to be noted is a tendency to local "interruption" of correlation, so that the latter is for a stage almost obliterated. This inference is drawn from the tendency to assume a horizontal direction presented by the breadth-line between ordinates C and D. Apart from this feature, I would remark only that I see no evidence of any "compensatory" decrease in breadth, even when the upper extreme in length is reached.

I prepared for comparison a number of charts based upon data published for other series, endeavouring to use those including about one hundred male crania. For special reasons, two series falling short of that number are included. Also I have made a few observations on cranial height, treating this dimension in the same way as cranial breadth, and using either basi-bregmatic (basal) height (BH), or auricular height (OH) for that purpose. The identity of the tracings is indicated with sufficient clearness in the several charts (IV. to XV.). In two instances (Charts III. and XII.) cranial breadth is employed as the basis of comparison. Subsidiary observations restricted to length and breadth relate to the subdivision of a particular group within a series (Chart XVI.), or again to the complete subdivision of a series into groups separated not as in the preceding examples by 5 mm. of length but by 1 mm. of that dimension. The groups are then increased greatly in number (Chart XVII.).

Finally, some observations of a general order are appended with Charts XVIII. and XIX.

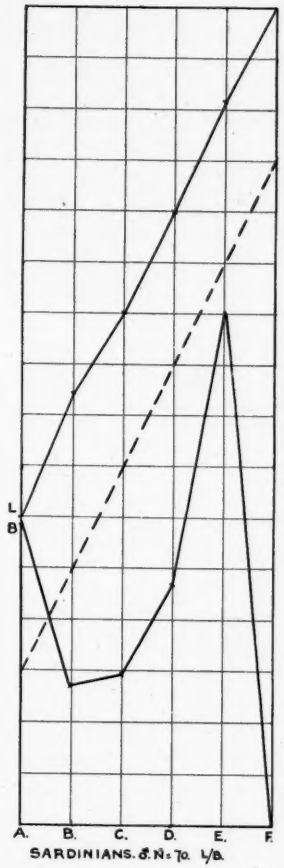


CHART V.

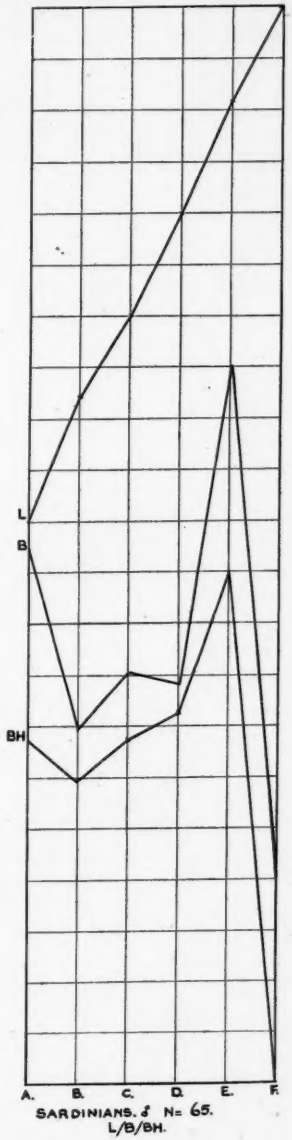


CHART VI.

The Charts (IV. to XV.) prepared for comparative purposes are based upon data from the following series:—

No. of Chart.	Designation of series.	No. of examples.	Literary reference.
IV.	Scottish "K."[1]	100	Young, *Trans. Roy. Soc. Edinburgh*, vol. li. part ii. No 9.
V., VI., VII.	Sardinian (modern).[1]	70	Duckworth, *Zeitschrift für Morphologie und Anthropologie*, Band xiii. Heft 3.
VIII., IX., X.	Naqada (Egypt).[1]	143	Fawcett and Lee, *Biometrika*, vol. i. No. 4.
XI., XII.	Australian aborigines.[1]	132	Turner, "*Challenger*" *Expedition: Zoology*, vol. x., "Human Crania," 1884. Basedow, "Der Tasmanierschädel," *Zeitschrift für Ethnologie*, Heft 1, 1910. Duckworth, *Journal of the Anthropological Institute*, 1894.
XIII., XIV.	Zürich.[2]	66	Czekanowski, *Inaugural Dissertation, Zürich*, 1907.
XV.	Tübingen.[2]	108	Ranke, *Die Anthropologische Sammlungen Deutschlands*, xvi., Tübingen, 1902.

The study of the charts thus obtained leads me to the following conclusions:—

1. While the line of length (representing the mode of increase in length) pursues an almost regular (*i.e.* uninterrupted) course in all the series, yet the line representing the accompanying change in breadth is always more or less irregular. In some instances the amplitude of the oscillations exhibits clearly the high degree of variability within a series. And although this conclusion may be formed from the study of columns of numerical data, yet the impression left by the inspection of the chart is likely to be deeper and more lasting. The chart serves as a summary of and as a substitute for the large numbers of data to which it owes an origin.

2. As a net result in every series, an increasing length carries with it increased breadth. Yet the latter dimension may pursue a course of extreme irregularity, even though the general result is such as is thus described. Of the series studied, the crania of Sardinians and of the aborigines of Australia exhibit this irregularity in the highest degree. These series possess only a low degree of correlation of length and breadth. But it is easy to understand that out of such a series as either of these a particular group of skulls might be selected which when investigated separately would provide indications of a much higher degree of correlation than the parent series taken as a whole.

3. The occasional and irregular occurrence of a fall in breadth (or height)

[1] Dolichocephalic series. [2] Brachycephalic series.

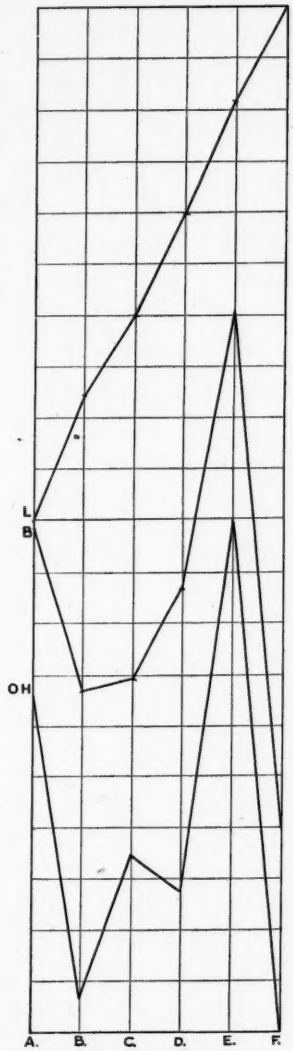


CHART VII.

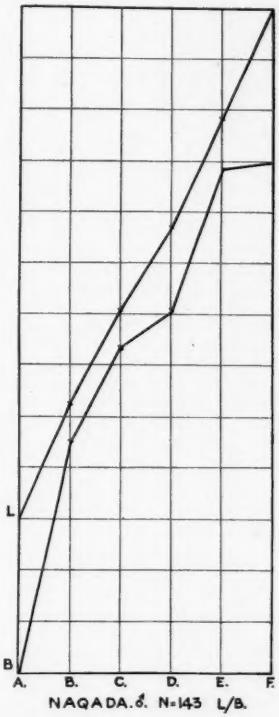


CHART VIII.

(shown in a particular part of a series with a continually increasing length) may be claimed as evidence of "compensation." But unless the decrease

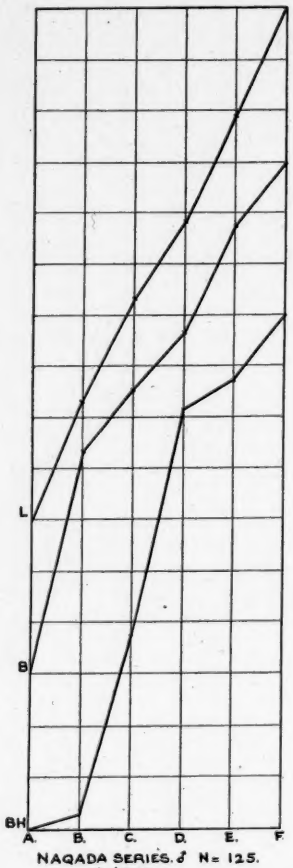


CHART IX.

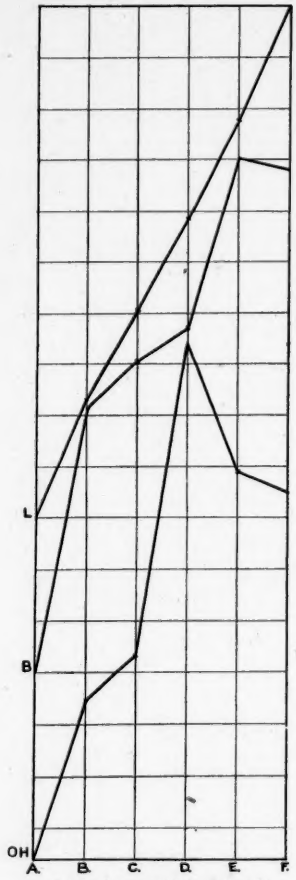


CHART X.

is uniformly exhibited, "compensation" can only be indefinite and vague in its reference. In the various series examined, such "compensatory" diminutions as are seen (and certainly the diminutions do occur) continue for a brief space and are limited.

4. No specific distinction has been detected as between brachycephalic and dolichocephalic series. But the brachycephalic series brought here

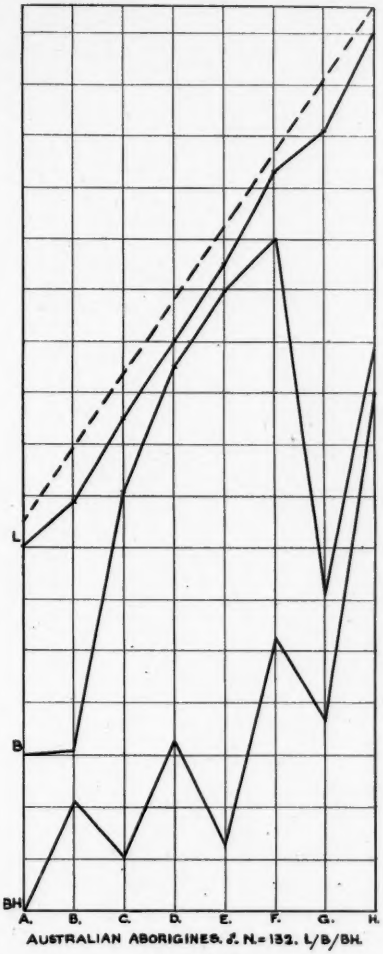


CHART XI.

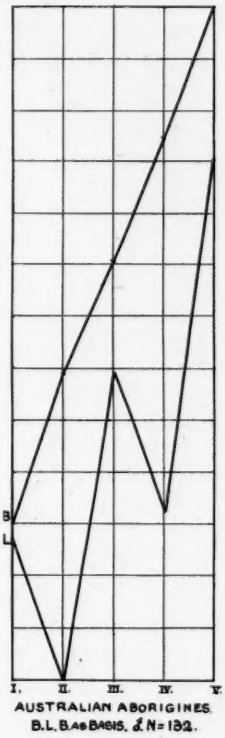


CHART XII.

into comparison provide indications of a more regular progression in respect of breadth-increase than do the dolichocephalic series.

5. Irregularities are more pronounced at the limits (upper or lower)

of a series. The Sardinian series (Charts V., VI., and VII.) is distinguished from all the rest by the fact that the lowest terms of breadth and height coincide with the highest term of length.

6. In some instances (*e.g.* Chart I., Series "DR," Groups C to D), a temporary interruption of correlation appears, for breadth remains constant in two successive groups (though length varies). But within the

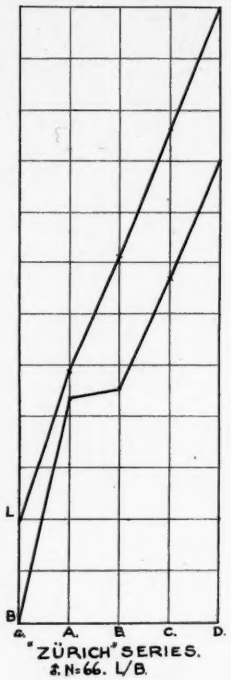


CHART XIII.

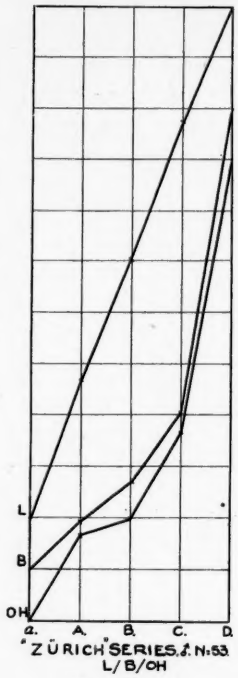


CHART XIV.

group of individuals concerned the several data can be reviewed, and a chart (*e.g.* Chart XVI.) can be constructed with reference to the particular group. The chart shows that therein correlation may still be observed. Consequently it is concluded that the method of grouping, viz. taking the average of successive groups whose lengths differ by 5 units, tends to mask variations which really exist. A simpler but more laborious mode of division is employed in the construction of Chart XVII., where the data provided by series "DR" have been employed again. In Chart XVII. the crania have been ordinated in groups corresponding to increments of

1 mm. of length. It is likely that this mode of division will prove more satisfactory than that actually applied in the majority of the charts, but so far it has been used in the case of Series "DR" alone.

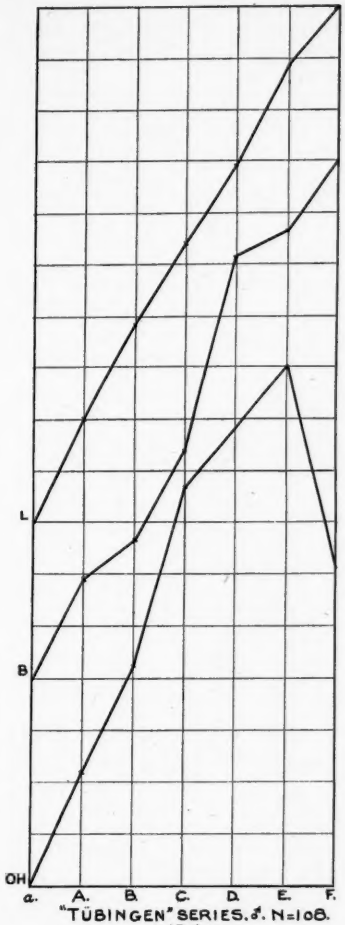


CHART XV.

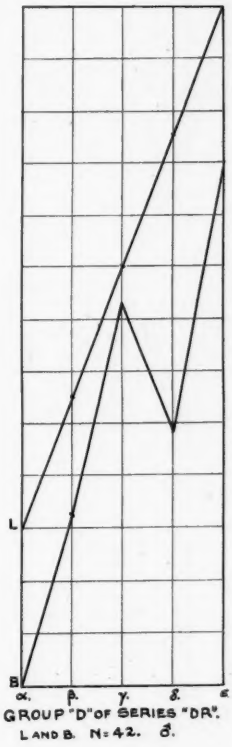


CHART XVI.

7. Sudden alterations in the direction of the "breadth-line" have been traced in numerous instances to particular specimens. These may be termed "aberrants" in contrast with their congeners. The charts show

how effective a small number of "aberrants" may be in determining the mean value of the group in which they fall. Evidently they will be more potent when they occur in a "terminal" group, *i.e.* at one or other end of a series, for here they find fewer associates to counterbalance their peculiarities. But they may occur in any part of a series, and their further investigation seems important or at least worthy to be undertaken.

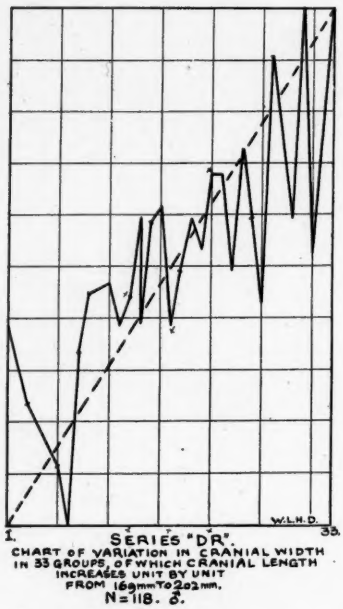

1.
33.
W.L.H.D.
SERIES "DR".
CHART OF VARIATION IN CRANIAL WIDTH IN 33 GROUPS, OF WHICH CRANIAL LENGTH INCREASES UNIT BY UNIT FROM 169mm TO 202mm.
N=118. ♂.

CHART XVII.

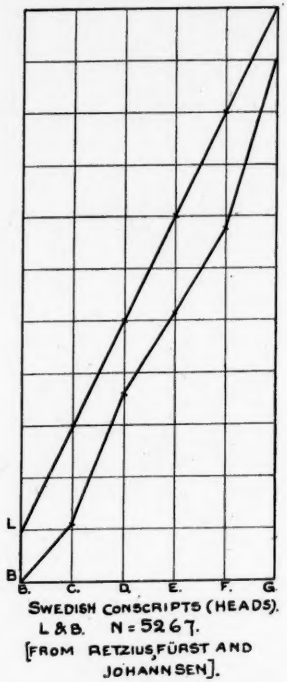


CHART XVIII.

8. The mention of the counterbalancing of individual peculiarities by the levelling mass of a large number of associated specimens leads to the consideration of the effect of actual numbers upon the appearances shown by the charts. Numbers are not always capable of "smoothing" a curve in these instances, and this is well illustrated by the contrast of the breadth-lines in Charts XI. (Aboriginal Australians) and XIV. (Zürich), where the more irregular line is associated with a much larger collection of individual data than the more regular line (132 as against 53).

Notwithstanding this consideration, I endeavoured to find a much larger series than any examined above. And remembering that some of the points I had been investigating (though they are not described here) are dealt with by Professor Johannsen in a paper published some years ago, I returned to the study of that memoir (Johannsen, "Über Dolichocephalie und Brachycephalie" in *Archiv für Rassen- und Gesellschafts-*

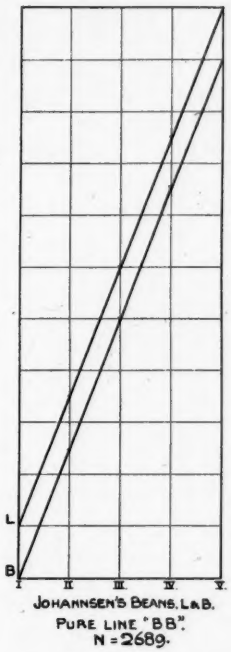


CHART XIX.

Biologie, Marz–April 1907). There I had the good fortune to discover data supplied by Professors Retzius and Fürst relating to several thousand Swedish conscripts. The data include head-length and head-breadth, and are published in such a form that the construction of a chart was easy. This chart (XVIII.) summarises observations on more than 5000 individuals, and the regularity with which the line of breadth mounts in conformity with that of length suggests strongly the damping effect of numbers. So far I have made no further tests of the kind.

But another reflection arises from the perusal of Professor Johannsen's

paper. The regular and co-ordinate course of length and breadth in the large Swedish series may owe its regularity to the numbers taken into account, yet again it may be due to the individuals of which the series is composed possessing a degree of homogeneity not encountered elsewhere (in the present communication). And the question arises as to whether the charts can provide any suggestion of homogeneity of type, and purity of race (assuming that a pure race is homogeneous in respect of type). The well-known difficulty of finding an example of a pure human race is an absolute bar to the preparation of a length and breadth chart illustrative of its cranial dimensions. Consequently I have had recourse to Professor Johannsen's beans. The Professor cultivated these beans for many seasons, and established stocks which he named "pure lines." The title was awarded upon considerations of the constancy with which the offspring reproduced the special parental characters. Most of the characters were not suitable for comparison with the data of human craniometry. But Professor Johannsen measured large numbers of the beans. And as the latter were of "reniform" contour, they provided length and breadth and a breadth index. These dimensions seemed to me appropriate to the purpose of preparing a chart which is submitted herewith (Chart XIX.). It is based upon observations bearing upon one of four "pure lines" described by Professor Johannsen. The other three "pure lines" yield charts so nearly resembling Chart XIX. as practically to be identical with it. Perhaps it is too far a cry to pass from beans to human crania, but the suggestion provided by Chart XIX. seems worthy of remembrance in any extension of craniological investigations on the lines indicated in this note.

Note on the Charts I. to XVII. and XIX.

The abscissæ correspond to the groups into which the various series of crania have been divided, the mode of division being shown in Table I. in the text. Cranial length is employed as the basis of division in most of the charts.

In Charts III. and XII. cranial breadth is substituted for length as the basis of division, and the abscissæ I., II., etc., correspond to groups of crania of breadth not exceeding 125 mm. (I.), or between 125·1 and 130 mm. (II.), and so on.

In Charts XIII., XIV., and XV. a group of crania of length less than that denoted by the group letter A (*cf.* Table I.) has to be recognised, and is designated Group "a."

In Chart XVI., α, β, γ, etc., denote groups of which the respective lengths are 186, 187 . . . 190 mm.

In Chart XVII. thirty-three abscissæ correspond to cranial lengths rising from 169 mm. to 202 mm. inclusive, and increasing by 1 mm. at each stage. The sequence of lengths is indicated by the interrupted line, that of breadths by the continuous line in this chart.

In Chart XIX. the abscissæ correspond to lengths from 9 mm. to 13 mm. inclusive.

Throughout the charts, L denotes the course pursued by cranial length, B that pursued by cranial breadth, BH that pursued by basi-bregmatic height, and OH that pursued by auricular height in the several series.

ABSENCE OF PRE-MAXILLA. By Cranston Walker, M.D., Ch.B., B.Sc.

(from the General Hospital, Birmingham).

The subject of this communication is a boy of fourteen years. He presented himself at the Casualty Department of the Birmingham General Hospital for a pain in the side, which proved to be due to herpes zoster. A somewhat broad and low bridge to the nose led to an examination of the face, and it was at once perceived that the pre-maxillary portion of the palate, with the incisor teeth, was absent (see figs. 1, 2).

The two front teeth presenting in the upper jaw are the canines—conical in shape. Behind them on each side are the two bicuspids and two molars, the third molars can be seen in the radiograph, not yet erupted. On the left side there is a persistent milk molar between the permanent canine and the bicuspid. There are thus five functional teeth on each side.

The biting surface of the upper teeth on each side is not level, but convex downwards, and the apices of the canines are 5 mm. higher than those of the bicuspids. The whole upper jaw is short. The mesial borders of the two canines are only 6·5 mm. apart; their apices are 19 mm. apart. The four upper incisors are absent. In the mesial plane there is a narrow cleft, which can be traced for 5 mm. above the level of the canine-gum.

The arch of the palate is rather high and narrow, but is completely closed. Radiography shows that there is apposition of the bony parts of the two alveolar processes in front, but not actual union. There are three well-marked palatal ridges on the left, and two on the right. The nose is flat and broad (fig. 1), and is unusually flexible. The nasal septum is complete, but can be seen radiographically to be incompletely ossified (fig. 2).

No other abnormality has been found. The upper lip is well shaped, with a fully developed vertical ridge on each side of the nasal septum.

The upper teeth do not overlap the lower in front, but meet them irregularly and incompletely; the boy was not conscious of any inconvenience. Neither his face nor his voice would strike a lay observer as unusual, and no abnormality had been suspected by his parents or his schoolmasters.

Anatomically, the abnormality consists of a deficient ossification of the nasal septum and a complete absence of the pre-maxilla (fig. 2). The latter deficiency has partially been made good by the two maxillary processes growing forwards and inwards, meeting in the mesial plane and bearing the two canines almost into the position of the central incisors.

The anatomical deficiencies are situated in what was the mesial nasal process of the embryo; other portions of the same process, such as the tip of the nose and the middle portion of the upper lip, show no deficiencies.

As to the origin of the defect, the available history is an uncertain guide. It is as follows:—

FIG. 1.

The mother was unconscious of any abnormality. When pressed for memories, however, she thinks the first teeth to erupt were the two upper front ones; she does not remember the order of the remainder. When three years old the boy had measles, and was seriously ill. He then pulled a tooth, or it may have been one or two teeth, with some "flesh" attached, out of his mouth, and handed it to her; she promptly threw the article away. Soon after this he was admitted to the Sick Children's Hospital, Birmingham. The mother does not remember any remark having been made there about his teeth, and the case cannot be traced among the hospital records. There is no history of any injury. There are two brothers and one sister younger, all normal. No case of hare-lip or cleft-palate is known in the family.

So far as any reliance can be placed on this history, it suggests that

the pre-maxilla was not congenitally absent, but that it sloughed away during an attack of measles—a very unusual event. In this case, the embryonic defect might be of the nature of a double cleft palate, without hare-lip, and with a deficiency of the nasal septum which allowed the pre-maxilla to separate from its upper attachments, and which also prevented the nasal septum from ossifying to the normal extent. There is no ready alternative explanation of a child of three handing teeth out of his mouth, since this age is too early for the shedding of milk teeth. The mother's

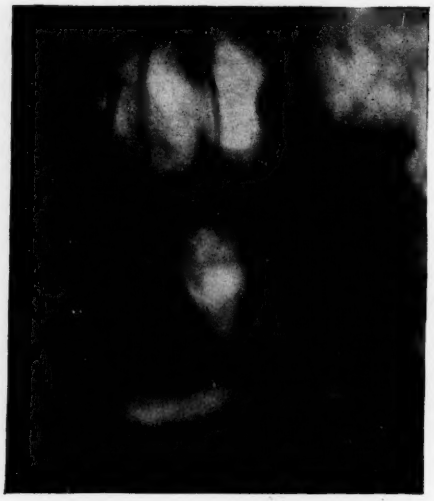


FIG. 2.

notion that the upper front teeth were the first to be cut is consistent, since if the original upper front teeth had been the canines, their eruption would have been preceded by several months by the lower incisor teeth. However, the growth and eruption of teeth in a pre-maxilla, which must have had very slender attachments to its surroundings, presents some difficulties.

A cast of the upper jaw and palate has been placed in the John Humphreys Odontological Museum of the Birmingham University. My thanks are due to Mr G. H. Teal for very kindly obtaining an excellent dental cast, and to Dr Emrys-Jones and the Radiographic Staff of the Birmingham General Hospital for facilitating the radiography and photography of the case.

SUMMARY.

1. The case shows complete absence of the pre-maxilla, with the four upper incisors, and deficient ossification of the nasal septum. Other malformations are absent.

2. The two maxillary processes have grown forwards and inwards, have met each other and the nasal septum in the mesial plane, carrying the canines into the incisor position, and have filled the space left by the pre-maxilla.

3. The history of the case is open to doubt, but it suggests that the pre-maxilla was sloughed at the age of three during an attack of measles. A previous deficiency of attachment must be supposed. Congenital defect of the mesial nasal process is evidenced by the condition of the existing nasal septum.

SOME NEW FACTS IN THE ANATOMY OF CERTAIN MOVEMENTS.

By EDGAR F. CYRIAX, M.D. Edin., *London.*

THE treatment by Swedish medical gymnastics, as is well known, consists to a large extent of localised movements of joints, which may be passive, purely active, or resisted. The study of these movements, whose number is practically unlimited, has brought forward a number of new facts, some of which I present herewith.

SHOULDER-JOINT.

The part played by the scapula during abduction and adduction of the shoulder-joint does not seem to be understood; the part played by it during flexion and extension of the shoulder-joint seems to be entirely ignored. In both these sets of movements the behaviour of the scapula is practically identical; it will therefore be necessary to refer only to one of them.

Modern anatomists are still somewhat at variance regarding the mechanism of abduction and adduction. It used to be laid down that the first half of the movement up to the horizontal was accomplished at the gleno-humeral joint, the scapula being fixed, and that the second half depended solely on rotation of the scapula. This is manifestly incorrect; it implies that the scapula rotates through an angle of 90°, so that at the conclusion of the movement its vertebral border is horizontal, which is not the case. At a later period certain observers stated that the scapula rotated most during the first half of the movement, and least during the last quarter.[1]

As a matter of fact, there are two methods of performing the movements of abduction and adduction of the shoulder:—

(*a*) As during everyday life, the scapula not being fixed.

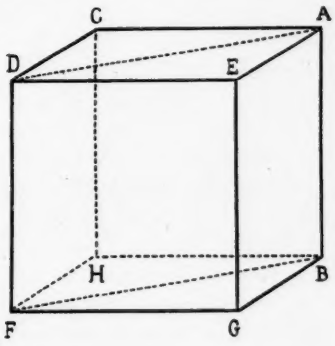
(*b*) As during active gymnastic exercises (whether applied medically

[1] See, for example, Cathcart, *Journ. Anat. and Phys.*, 1884, xviii. 211; Cleland, *ibid.*, 275; Cleland and Mackay, *Human Anatomy*, 1896, pp. 155, 267; Dalla Rosa, *Physiologische Anatomie des Menschen*, 1898, vol. i. p. 283; Mollier, *Statik und Mechanik des menschlichen Schultergürtels unter normalen und pathologischen Verhältnissen*, 1899; Steinhausen, *Arch. f. Anat. u. Phys.*, Phys. Abth., Suppl., 1899, 403; Thöle, *Arch. f. Psych.*, 1900, xxxiii.; du Bois-Reymond, *Ergebn. d. Physiol.*, 1903, pt. ii., 621; Demeny, *Méchanisme des mouvements*, 1904, 39; De Laroquette, *Rev. internat. de méd. et de chir.*, 1910, xxi. 193.

or educationally), the scapula being kept drawn inwards and backwards as much as possible during the entire time of execution of the movement.

In the former of these cases, the facts are that the scapula rotates most during the first quarter, less during the second, still less during the third, and least during the last quarter. In the latter case, during the first half the scapula remains practically immovable, the movement taking place only at the gleno-humeral joint. After the horizontal has been reached, the movement is continued almost exclusively by rotation of the scapula; this soon begins to diminish, the movement being resumed by the gleno-humeral joint, so that at the final stage of the movement it is almost exclusively the latter, just as it was at the commencement.

I should also like to say a few words concerning the number of move-



ments possible in the shoulder-joint. This joint is of the ball-and-socket variety, and therefore permits of angular movement in every direction, as well as rotation. This may be represented graphically as follows:—Let A represent the shoulder-joint, and AB the longitudinal axis of the humerus when the arm is dependent, and AC the same axis when the humerus is abducted through a right angle. Complete the cube ACDFGB, and draw the diagonals AD, BF. Then movements of flexion and extension of the humerus will take place in the plane ABGE, movements of abduction and adduction in the plane ABHC, and a combination of the two in an intermediate plane such as ABFD; rotations will take place in the line AB, or any other line radiating from A. Now, suppose the humerus to be first flexed to a right angle so as to assume the direction AE, and then to be moved in the plane AEDC, so that it ultimately assumes the direction AC, we have in this and then the reverse back to AE a movement of the humerus which at present is not recognised, and has no

name in anatomy books, although in Swedish gymnastics it is known as arm carrying outwards and inwards. In ordinary life this movement is of frequent occurrence, as, for example, when transferring books from one place to another on the same shelf.

Elbow-joint.

I wish to make some remarks on the muscles involved in flexion and extension of this joint; they are best studied by performing these movements against resistance applied over the wrist or its neighbourhood. As regards the muscles of the upper arm that aid in these movements, the biceps and brachialis anticus act in flexion, and the triceps and anconeus in extension, and this holds good whatever the position of the radio-ulnar joints. Variations in the latter, however, very greatly modify the action of the forearm muscles, *e.g.*:—

(*a*) When the forearm is completely pronated. Flexion is assisted by the *extensors* on the back of the forearm together with the supinator longus, the tension being felt most in the latter muscle and the extensor carpi radialis longior. Extension is aided by the *flexors* on the front of the forearm, the tension being felt most in those on the ulnar side.

(*b*) When the forearm is in the mid-position. Flexion is assisted by the extensors and flexors on the radial side of the forearm, the tension being felt most in the supinator longus. The extensors and flexors on the ulnar side of the forearm are in action during extension.

(*c*) When the forearm is completely supinated. The flexors of the forearm assist in flexion, and the extensors in extension, as ordinarily stated; the tension is, however, felt most in the muscles of the upper arm, not in the forearm, as in the case of pronation or the mid-position.

Wrist-joint.

I cannot remember ever having seen an anatomy text-book refer to the movement of rotation of the wrist-joint, although they all mention such rotation as being present in the joints of the phalanges. This movement at the wrist-joint can be readily demonstrated; the radius and ulna are fixed by the surgeon's one hand; the other, grasping the patient's hand in the same manner as if to shake hands, rotates it first in one direction and then the other. The amount of such rotation obtainable is about through 45° to 60°. This of course represents the amount of passive rotation; active rotation is impossible.

Ankle-joint.

The calf muscles—gastrocnemius, soleus, and plantaris—are generally considered as being the muscles that are active in extension of the ankle-joint. This is not true of every position of the foot. If the subject sit on a table so high that the lower leg does not touch the ground, and then extend his foot as much as possible, none of the calf muscles are placed in action, the tendo Achillis not even being rendered taut. The only active muscles appear to be the tibialis posticus and peronei.

Lumbar Vertebræ.

Anatomy text-books either state that there is no rotation at all in the lumbar vertebræ, or else assert that it is present in such small amount as to be a negligible quantity. No book that I have met attempts to describe a *modus operandi* of testing for this movement. The simplest way is to lay the subject on his face, and, while firmly fixing the lowest dorsal vertebræ with one hand, lift up the anterior superior spine of one side with the other. Normally it ought to be quite easy to raise it about two inches without the dorsal vertebræ participating in the movement. This is effected by rotation which takes place exclusively in the joints of the lumbar vertebræ, and roughly speaking corresponds to about 10°.

NEW PUBLICATIONS.[1]

GIORNALE PER LA MORFOLOGIA DELL' UOMO E DEI PRIMATI. Edited by Professor G. L. SERA, University of Padua. 1917. Vol. I. Part I.

WE extend a most hearty welcome to this new journal, which is to be devoted to papers and researches connected with the morphology of Primates, with man as the central figure. The editor, Professor G. L. Sera, indicates the exact scope of the journal in a preliminary article. Three papers appear in the first number: (1) On the Penis of Macacus, by O. de Beaux; (2) Marsupial Features in the Human Mandible, by C. Pelizzola; (3) The Biological Value of Sera's Empirical Curve, by A. Giardina. There is also included a review of Pilgrim's recent paper on the Siwalik Primates.

THE BASLE ANATOMICAL NOMENCLATURE (B.N.A.). By E. B. JAMIESON, M.D., M.B., Ch.B. (Edin.), Lecturer on Anatomy, University of Edinburgh. 1916. Green & Son, London and Edinburgh. (Price 6s.)

DR JAMIESON has performed a very useful service in preparing an alphabetical list of terms showing the old terminology, the B.N.A. terminology, and the suggested English equivalent. In a majority of cases the old terminology seems to us preferable to the new..

APPLIED ANATOMY: THE CONSTRUCTION OF THE HUMAN BODY CONSIDERED IN RELATION TO ITS FUNCTIONS, DISEASES, AND INJURIES. By GWILYM G. DAVIS, M.D., Professor of Orthopedic Surgery in the University of Pennsylvania. Fourth edition. Lippincott & Co., Philadelphia and London. 1916. (Price 24s.)

THIS profusely illustrated work on applied anatomy first appeared in 1910, and is now in its fourth edition. In its latest form some new matter has been added to the text, while several of the illustrations have been improved.

[1] The Editorial Committee would welcome notes on new publications.

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Anatomical Society's Proceedings, 309.
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